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Special Technical Report 28

EVALUATION AND PREDICTION OF MAXIMUM USABLE FREQUENCY (MUF) OVER BANGKOK

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By: CLIFFORD L. RUFENACH

Prepared for:

U.S. ARMY ELECTRONICS COMMAND
FORT MONMOUTH, NEW JERSEY 07703

CONTRACT DA 36-039 AMC-00040(E)
ORDER NO. 5384-PM-63-91

STANFORD RESEARCH INSTITUTE
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ABSTRACT

Two sets of corrected monthly median MUF (vertical incidence) predictions are compared against the monthly median observed vertical incidence sounder values over Bangkok for the period April 1965 through August 1966. The comparison showed a definite improvement in accuracy of the corrected predictions relative to the standard predictions and indicated the desirability of using the same method for generating corrected predictions for 1967. New predictions for 1967 were derived by adding a correction to the standard predictions obtained from a method developed by Stanford Research Institute, long-term predictions can be prepared for several years in advance with this method. The predictions for 1967, corrected for the Bangkok area, typically vary between about 3 MHz in the early morning to about 10 MHz in the late afternoon.

The predicted MUF's for 1967 average about 1 MHz higher than 1966, which indicates that the 1967 operating frequencies may be increased by about 1 MHz without increasing the expected communication outage.

CONTENTS

TABLES

ILLUSTRATIONS

PREFACE

The work described in this report has been carried out in Bangkok, Thailand, by personnel of the Military Research and Development Center Electronic Laboratory (MRDC-EL), as part of Project AGILE, a program of the U.S. Advanced Research Projects Agency (ARPA). The ARPA supports MRDC, a joint Thailand/U.S. organization, through its Research and Development Field Unit, Thailand. The Communication Laboratory of Stanford Research Institute, in connection with the ARPA Southeast Asia Communication Research (SEACORE) program, participates in operating the MRDC-EL under ARPA Contract DA 36-039 AMC-00040(E). This report is published under Task B of that contract, "Ionospheric and Frequency Spectrum Investigations," and uses ionosonde data observed on the C-2 sounder, operated in Bangkok by the MRDC, to evaluate the accuracy of past predictions and to correct the predictions for 1967.

ACKNOWLEDGMENT

It is the author's pleasure to acknowledge the work of Mrs. E. A. Clarke of SRI, Menlo Park, California in helping prepare the predictions for 1967 using the U.S. Army Radio Propagation Agency computer program.

I INTRODUCTION

A. BACKGROUND

The attenuation of groundwave radio signals propagated in heavily forested areas is significantly larger than in nonforested areas. High-frequency (HF) skywave paths provide an alternative to groundwave paths, which can overcome this communication limitation. Skywave propagation becomes especially attractive for low-power transceivers operating over short distances (0-200 km) in forested areas. Therefore, analysis and prediction of ionospheric behavior are of great importance to the frequency allocator and to the operation of present HF sets as well as the design of future HF transceivers.

Although the use of skywave eliminates the problem of groundwave attenuation, the variation of the useful skywave frequency range with time of day must be considered. The frequency range over which successful communication is anticipated is called the useful frequency spectrum. It is bounded on the upper end by the maximum usable frequency (MUF) and on the lower end by lowest usable frequency (LUF). The MUF is usually determined by the maximum frequency reflected from the F layer and is independent of the communication system. The LUF is typically determined by the noise environment and the received signal strength and is dependent on the transmitter power, receiver bandwidth, etc., and can only be specified for a given communication system.

For short paths (near vertical incidence), the F2 layer critical frequency is a good measure of the MUF (zero range). In order to gather data for studying the ionospheric radio propagation behavior, including the development of a correction to the MUF predictions at Bangkok, a vertical-incidence sounder was installed at the MRDC Electronics Laboratory. This sounder has been operating continuously since September 1963 and monthly ionospheric data reports have been published.[1,2*]

*References are listed at the end of the report.

B. SUMMARY OF EARLIER WORK

Much work has been done on the problem of predicting the MUF since the early 1940's.[3-9] The Central Radio Propagation Laboratory (CRPL) of the National Bureau of Standards (NBS)* and Stanford Research Institute (SRI) have developed electronic computer programs for prediction of MUF.[10-13] NBS has for many years been providing data on MUF based on the numerical mapping method of W. J. Jones and R. M. Gallet.[10] This mapping method allows easy revision of the predictions by recent ionospheric data, and the predictions are issued for about three months in advance; however, predictions one or two years in advance may be computed if the sunspot number is specified. The SRI electronic computer prediction program, developed for the U.S. Army Radio Propagation Agency (RPA),[13] is very useful for long-term predictions (several years in advance) since the computer predictions need not be modified by current ionospheric data, but only by a reasonable estimate of sunspot number.

In a recent study,[14] the predictions of F2 critical frequency obtained from two of these prediction methods (NBS and SRI/RPA) for September 1963 through March 1965 were compared with measured values obtained at Bangkok. On the basis of this comparison, an average correction function was calculated for both of the prediction methods. The average correction function was then applied to predictions for 1965 and 1966 for each prediction method to obtain both predictions for 1965-1966.

C. OBJECTIVES OF PRESENT WORK

All work in this report is concerned with MUF predictions. LUF prediction is outside the scope of this report.

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*Now called the Institute of Telecommunications Sciences and Aeronomy (ITSA) of the Environmental Science Services Administration (ESSA).

The purposes of this report are as follows:

(1) Compare the corrected NBS and SRI/RPA MUF predictions derived in Ref. 14 with monthly median values of the F2 layer critical frequency observed on the vertical incidence sounder to determine the prediction accuracy.

(2) Evaluate the effectiveness of the correction functions derived in Ref. 14.

(3) Generate a new correction function based on 1965-1966 data and apply it to predictions for 1967 to obtain 1967 predictions for the area of Bangkok, Thailand.

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II METHOD OF APPROACH

A. DATA SOURCE

The foF2 monthly median observed values were taken from the monthly published ionospheric data reports.[1,2] These median values were calculated from daily values, which are scaled from hourly vertical-incidence sounder ionograms. The predicted monthly median foF2 values (MUF zero range) were taken from Ref. 14 for the corrected predictions and from the SRI/RPA electronic computer output[13] and the NBS world-wide maps[15] for the standard predictions.

B. COMPARISON

To facilitate the comparison of monthly median foF2 data, both the predicted and observed values were plotted as a function of local time. A typical comparison plot is given in Fig. 1, showing data for the SRI/RPA predictions for the month of May 1965. The upper plot shows both the standard and the corrected predictions and the observed monthly median values. The observed data were taken from the foF2 column of the median values table of the May 1965 Ionospheric Data Report.[1] The corrected prediction data for SRI/RPA was taken from Fig. C-2 in Appendix C of Ref. 14, while the standard prediction data were taken from the output of the electronic computer program of Ref. 13. The difference between the predicted and observed data was calculated and plotted on the lower graph, giving separate error functions for the standard and corrected predictions. The same procedure was followed for each month from April 1965 through December 1965 for the NBS prediction comparison and from April 1965 through August 1966 for the SRI/RPA prediction comparison.

C. EVALUATION

The evaluation of prediction effectiveness was performed in three separate ways: diurnal error function comparison, mean total error comparison, and error distribution comparison.

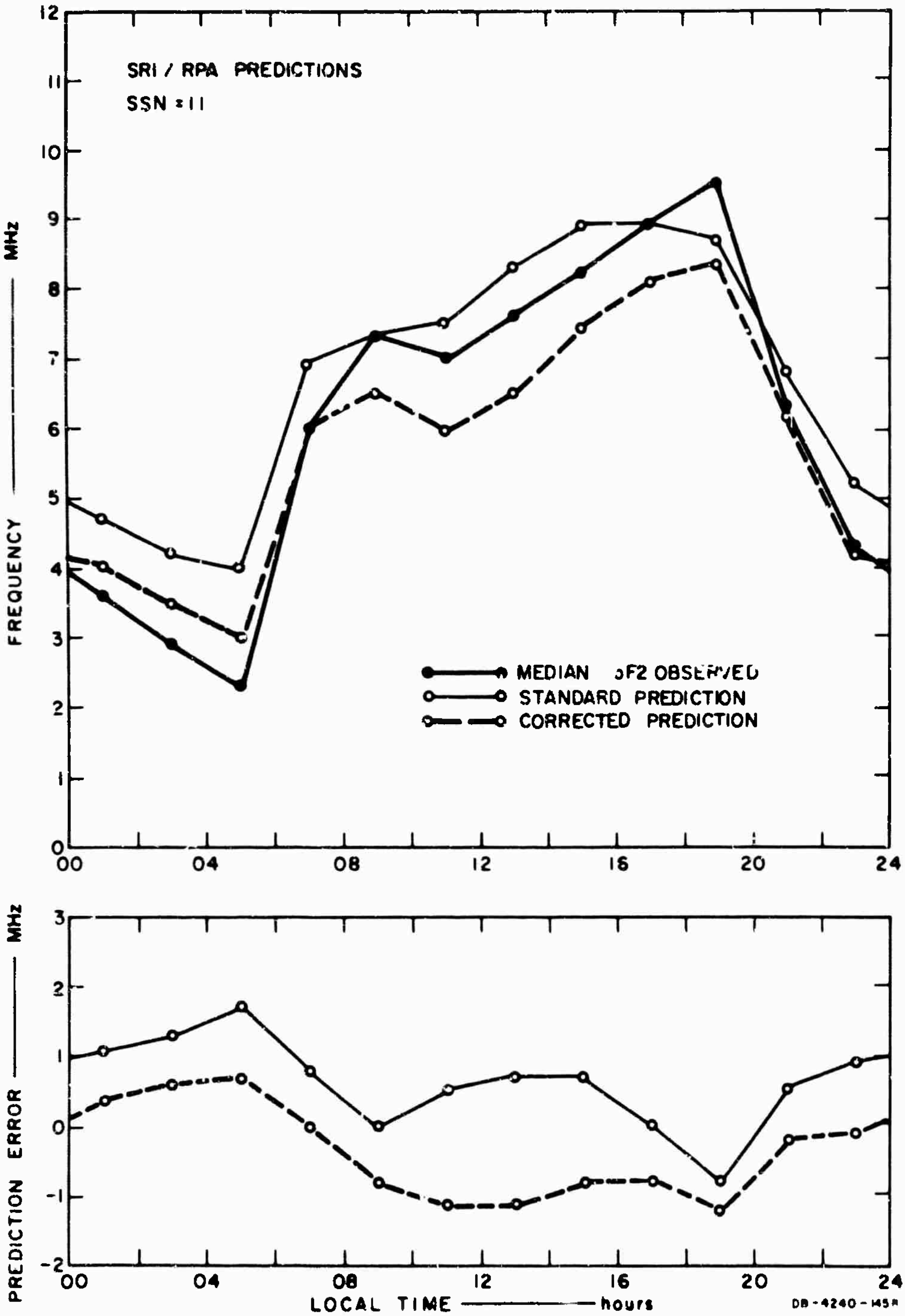

FIG. 1 COMPARISON OF OBSERVED AND PREDICTED MONTHLY MEDIAN foF2 FOR MAY 1965

The first technique uses the median and quartile values of the prediction error as a function of local time to compare diurnal error function. These median and quartile values were calculated, taking into account the sign of the error, from the monthly error functions at two-hour intervals for the following cases:

(1) SRI/RPA standard predictions over the 17-month prediction period.

(2) SRI/RPA corrected predictions over the 17-month prediction period.

(3) NBS standard prediction over the 9-month prediction period.

(4) NBS corrected predictions over the 9-month prediction period.

The median error functions were replotted in pairs of interest as follows:

(1) SRI/RPA standard and corrected predictions.

(2) NBS standard and corrected predictions.

(3) SRI/RPA corrected and NBS corrected predictions.

The median values show how close the predicted values fit the actual observed values as a function of local time over the prediction period. A positive error corresponds to a predicted value higher than the observed value. The quartile values show the error variation as a function of local time over the prediction period. The median error functions were replotted in pairs of interest allowing a direct comparison of each pair (SRI/RPA and NBS) of error curves.

The mean total error comparison technique uses the mean value of the median error functions obtained by summing the median error function each two hours and dividing by the total number of hours summed. The sign of the error function value was not considered. The mean values

were tabulated for the above four cases. These four numerical values are the mean total error values for the period covered by the prediction and allow a simple comparison of the four predictions independent of local time and monthly variation.

The error distribution technique measures the percentage of time that the error is less than a given amount (cumulative error distribution function). For each error function, positive and negative errors were tabulated. The percent of time that the error is less than a given amount is obtained by summing the tabulated number of times the error function is equal to a given amount and dividing by the total number of occurrences. These percentages were calculated and plotted for the same above four cases, and are useful for determining the percentage of time the predictions are high or low for given allowable error (difference between predicted and observed values).

The overall evaluation requires that all three above techniques be considered, since each method gives new information. The first technique allows the important diurnal changes of both the median prediction error and its variations to be evaluated simultaneously on one plot for each prediction. The second technique allows comparison of a simple direct mean total of the error for the four different predictions, independent of local time. The third technique allows determination of the percentage of time that the predictions are high or low for a given allowable amount of error. The first technique gives the most comprehensive information, while the second technique gives more specific information. The third technique also gives considerable information; however no information on diurnal variations is included, making this technique less comprehensive than the first.

D. CORRECTED PREDICTIONS FOR 1967

The corrected predictions for 1967 were generated for the SRI/RPA method from the monthly standard predictions and a median correction function. The andard predictions for each month during 1967 were calculated by computer using the program given in Ref. 13. The median correction function for 1967 was derived from the comparison of the

observed and predicted values during the April 1965 through August 1966 prediction period and is identically equal to the standard prediction median error function for that entire period. This function gives the correction values at each two-hour interval for the 1967 prediction period. The corrected predictions for 1967 were derived by subtracting the median correction function from the standard predictions.

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III RESULTS

A. COMPARISON

The comparison of the monthly median predicted and observed foF2 value at Bangkok as a function of time of day were made. This comparison and the error function derived from this comparison are shown in two sets of curves in Appendices A and B, for the SRI/RPA predictions and for the NBS predictions, respectively.

B. EVALUATION

The results of the effectiveness of the prediction correction are evaluated by three separate techniques.

1. Diurnal Error Function Comparison

Figure 2 shows the median and quartile values of the error as a function of local time for all four predictions. These are derived from the entire period covered by each prediction. The median error function values for the four predictions vary from about -1.0 to 1.4 MHz with the largest values occurring in the early morning and near midday. The two standard predictions both show a large positive median error near midday. The SRI/RPA standard predictions also show a large positive median error in the early morning hours. The NBS median corrected error function averages slightly positive while the SRI/RPA median corrected error function is generally negative with the NBS corrected error function the closest to zero.

The SRI/RPA and the NBS error functions both have the same quartile ranges for the standard and corrected error function values, since a constant correction for each two-hour period was added to the standard predictions to obtain the corrected predictions. In addition, the SRI/RPA and the NBS quartile ranges are of similar magnitude over their prediction periods. The maximum value of the quartile range (about 1 MHz) occurs near midnight for both SRI/RPA and NBS predictions, while the minimum occurs near midday for SRI/RPA predictions and just before sunrise for the NBS predictions.

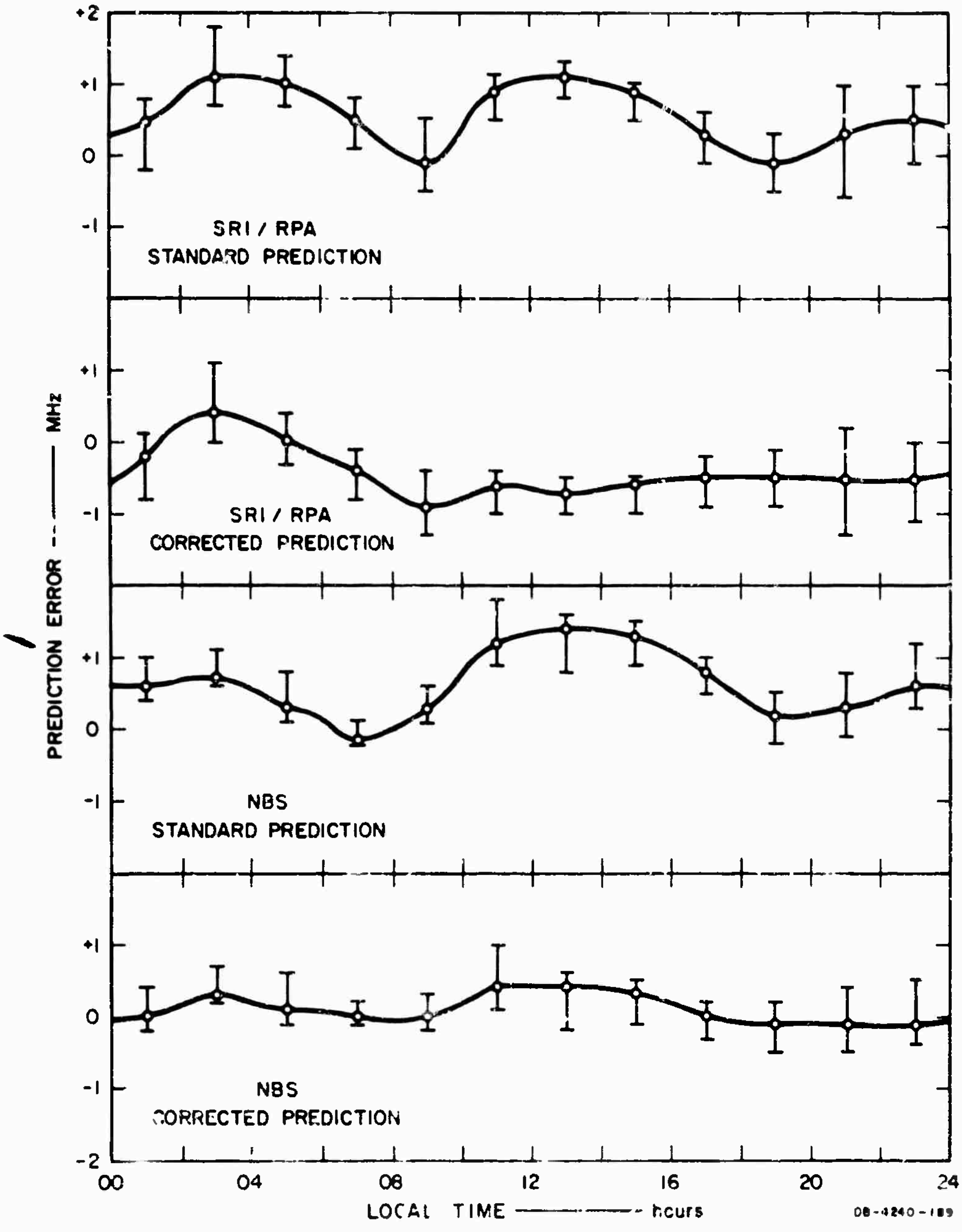

FIG. 2 MEAN AND QUARTILE VALUES OF THE ERROR FUNCTION

Figure 3 shows the median error as a function of local time (from Fig. 2) in pairs of interest. The SRI/RPA standard error function shows several maxima of about +1.0 MHz and several minima near zero prediction error. In comparison the SRI/RPA corrected error function shows a single maximum near +0.5 MHz in the early morning, followed by a decrease to a broad flat minimum continuing from sunrise to midnight. The NBS standard error function shows a maximum of +1.5 MHz near midday. In comparison the NBS corrected error function shows a broad, flat, essentially constant value for all hou of the day near zero prediction error The SRI/RPA corrected error function is negative except for several hours in the early morning. In comparison, the NBS corrected error is generally close to zero.

2. Mean Total Error Comparison

Table I shows the mean total values (for the period studied) of the median error function for all four predictions. It is easily seen from Table I that the SRI/RPA and NBS error were similar before the corrections were applied and that the NBS error was less after the correction was applied. The SRI/RPA error was slightly less after the correction was applied. The improvement averaged 0.50 MHz for the NBS predictions and 0.13 MHz for the SRI/RPA predictions.

Table I

MEAN TOTAL PREDICTION ERROR

Prediction Method	Standard Predictions	Corrected Predictions
SRI/RPA	0.61 MHz	0.48 MHz
NBS	0.65 MHz	0.15 MHz

3. Error Distribution Comparison

Figure 4 shows the percent of time the prediction error was less than a specified amount (for both positive or negative error). The SRI/RPA and NBS predictions both had predominantly positive error before the correction was applied. The SRI/RPA predictions have a slightly positive error after the correction has been applied.

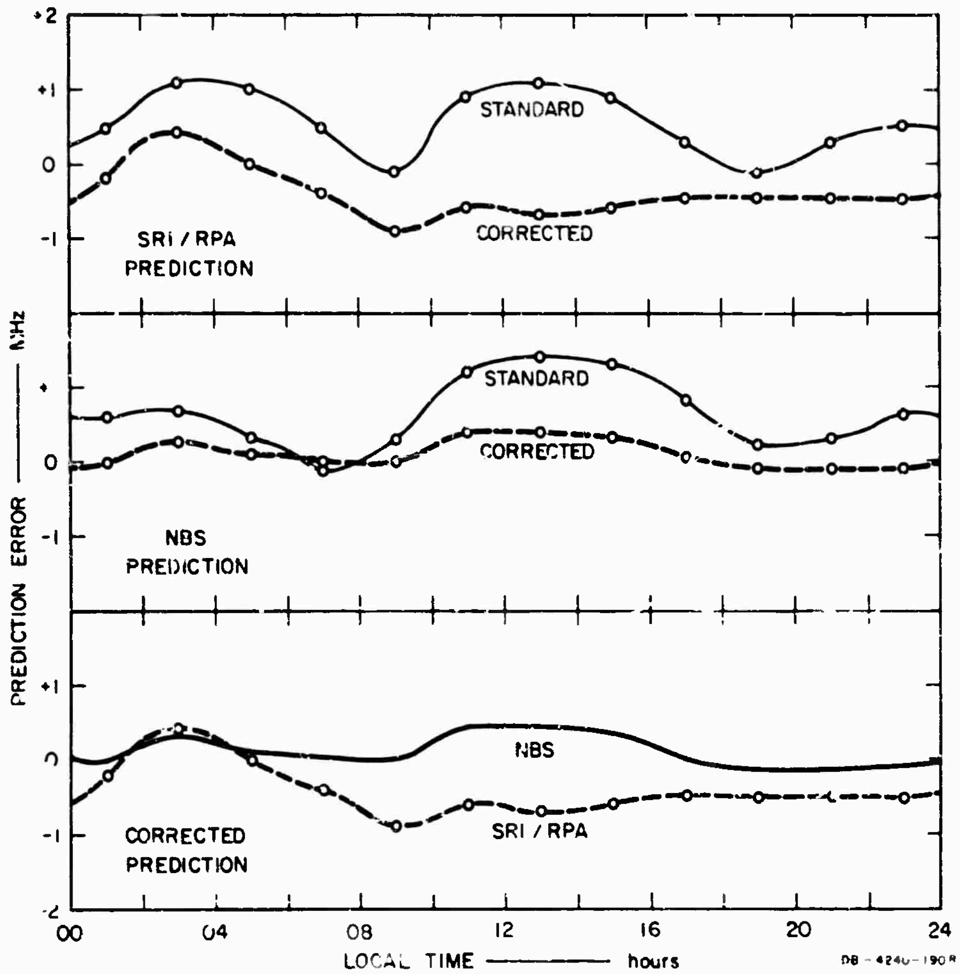

FIG. 3 COMPARISON OF MEDIAN ERROR FUNCTIONS

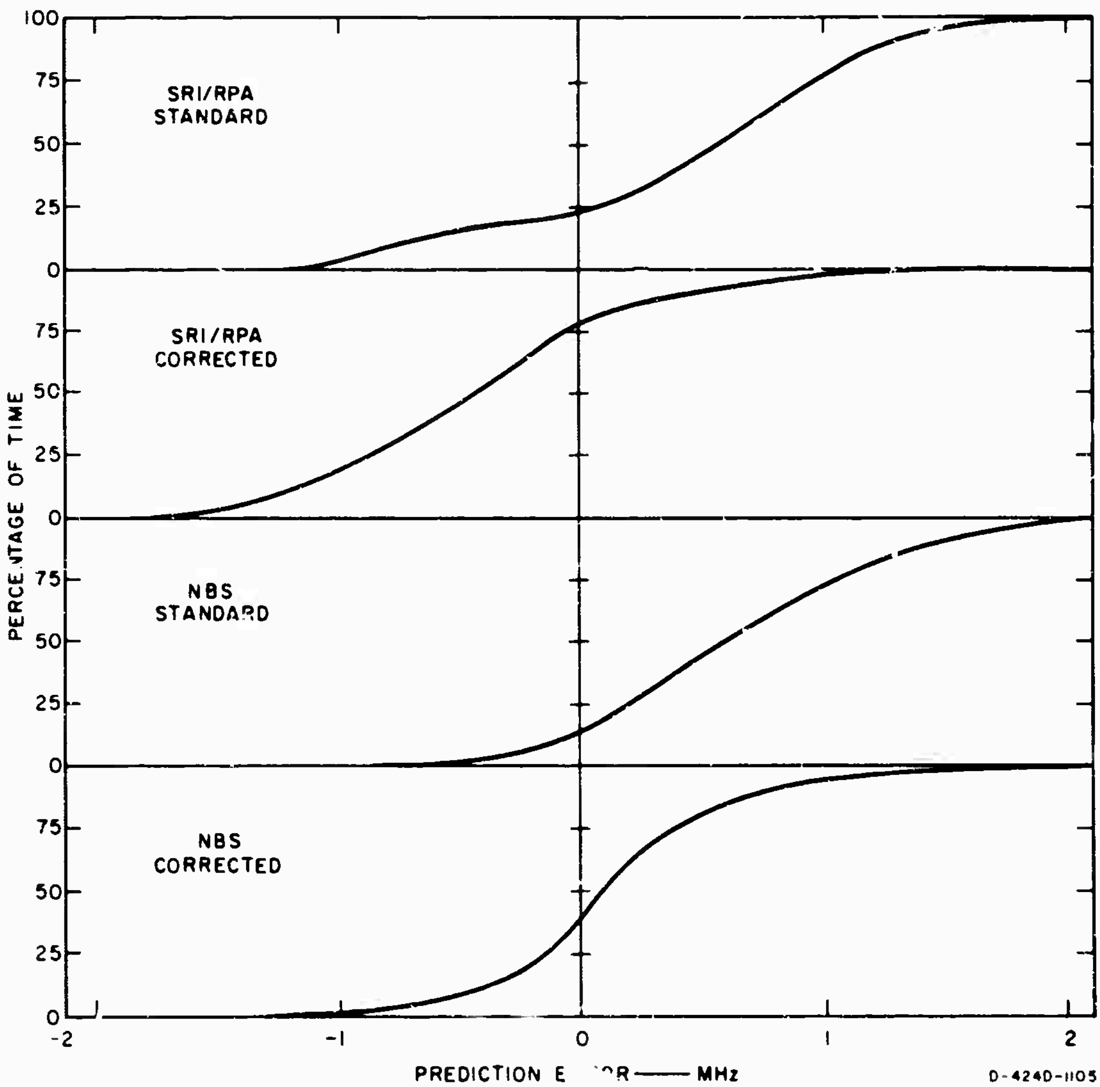

FIG. 4 PERCENTAGE OF TIME THAT PREDICTION ERROR IS LESS THAN ABSCISSA VALUE

Table II shows the percentage of time the magnitude of the error was less than 0.25, 0.50, 0.75, and 1.0 MHz. The values in Table II were derived from the data used in Fig. 4.

Table II

PERCENT OF TIME PREDICTION ERROR IS LESS THAN 0.25, 0.50, 0.75, AND 1.0 MHz

Magnitude of Error (MHz)	Prediction Method	Standard Prediction Positive (%)	Standard Prediction Negative (%)	Standard Prediction Total (%)	Corrected Prediction Positive (%)	Corrected Prediction Negative (%)	Corrected Prediction Total (%)
0.25	SRI/RPA	10	4	14	6	17	23
	NBS	17	7	24	29	20	49
0.5	SRI/RPA	24	7	31	10	33	43
	NBS	32	10	42	43	30	73
0.75	SRI/RPA	39	12	51	15	47	62
	NBS	47	12	59	52	35	87
1.0	SRI/RPA	53	18	71	18	59	77
	NBS	60	12	72	57	37	94

Table II illustrates the same general information as Fig. 4. In addition it shows the percentage of time the error was positive and negative. An increase in the total percentage of time that the error was less than a specified amount indicates an improvement in the prediction accuracy. For a specified amount, 0.25 MHz, from Table II, the typical percentage changes from one prediction method to another are given as follows:

(1) SRI/RPA, standard to corrected prediction (14 to 23 percent), 9 percent difference

(2) NBS, standard to corrected predictions (24 to 49 percent), 25 percent difference

(3) SRI/RPA corrected to NBS corrected predictions (23 to 49 percent), 26 percent difference.

These changes follow the same general percentage of change pattern for the other three specified amounts, 0.5, 0.75, and 1.0 MHz. The SRI/RPA predictions show a standard-to-corrected prediction improvement from 6 to 12 percent, while the NBS predictions shows a standard-to-corrected prediction improvement from 22 to 31 percent. The NBS corrected predictions show from 17- to 30-percent improvement over the SRI/RPA corrected prediction.

The overall results are:

(1) The NBS predictions were definitely most accurate when the correction function was applied, and

(2) The SRI/RPA and NBS predictions both showed prediction improvement when the correction function was applied.

The three evaluation techniques each verify the above results. The first technique showed that the NBS predictions were the most accurate for all times of day when the correction was applied and that the corrected predictions were more accurate than the standard predictions for all times of day and for both prediction methods. The second technique shows that the average prediction error is less when the correction is applied to both the standard predictions with the NBS predictions showing the greatest improvement. The third technique shows a definite increase in the percentage of time the prediction error is less than a specified amount when the correction function is applied for both SRI/RPA and NBS predictions. The NBS prediction shows the greatest percentage increase indicating the greatest improvement.

C. CORRECTED PREDICTION FOR 1967

The SRI/RPA corrected predictions for the calendar year 1967 are shown in Figs. 5 through 16. The sunspot numbers (SSN) used for the prediction are indicated on each figure.

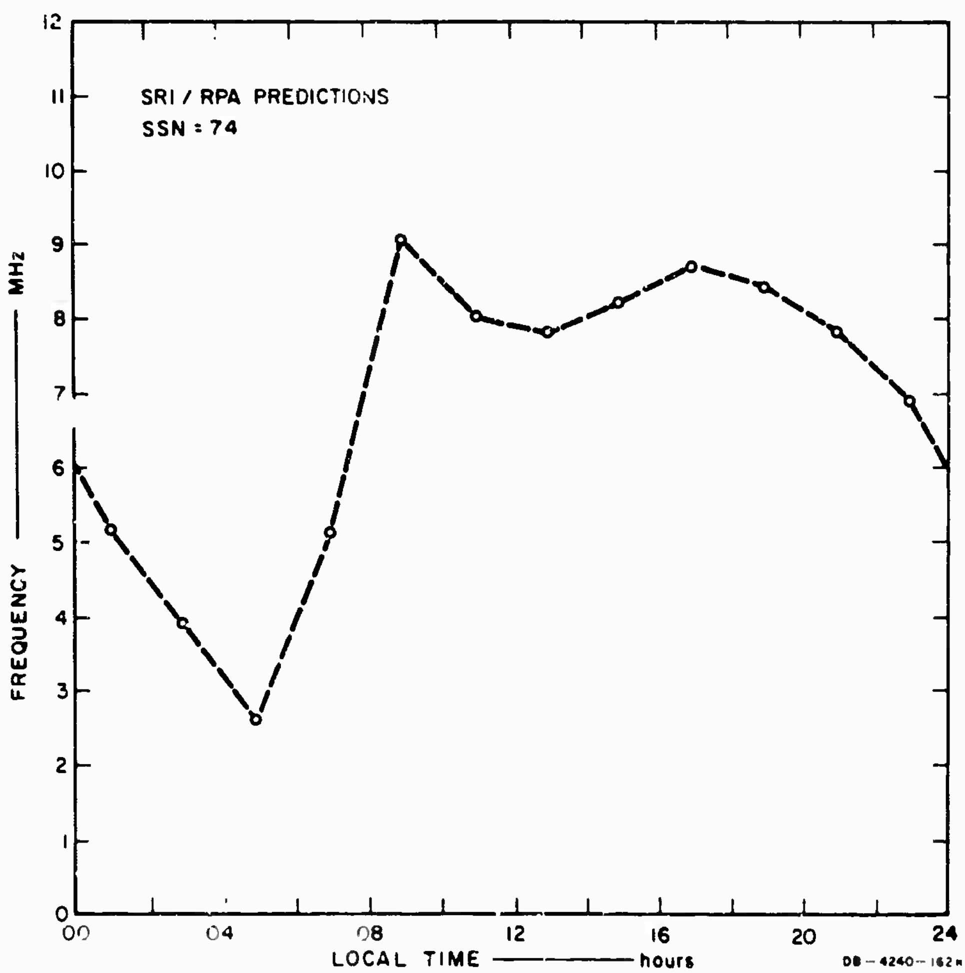

FIG. 5 CORRECTED foF2 PREDICTIONS FOR JANUARY 1967

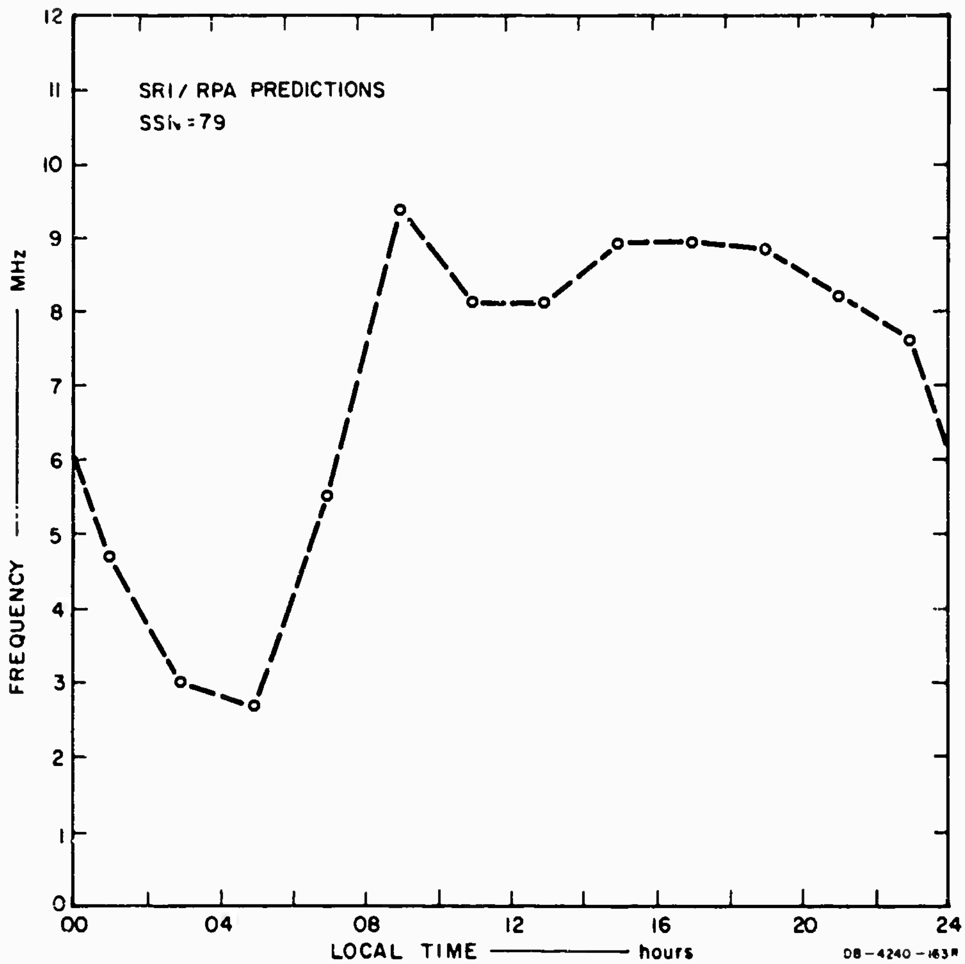

FIG. 6 CORRECTED f_oF2 PREDICTIONS FOR FEBRUARY 1967

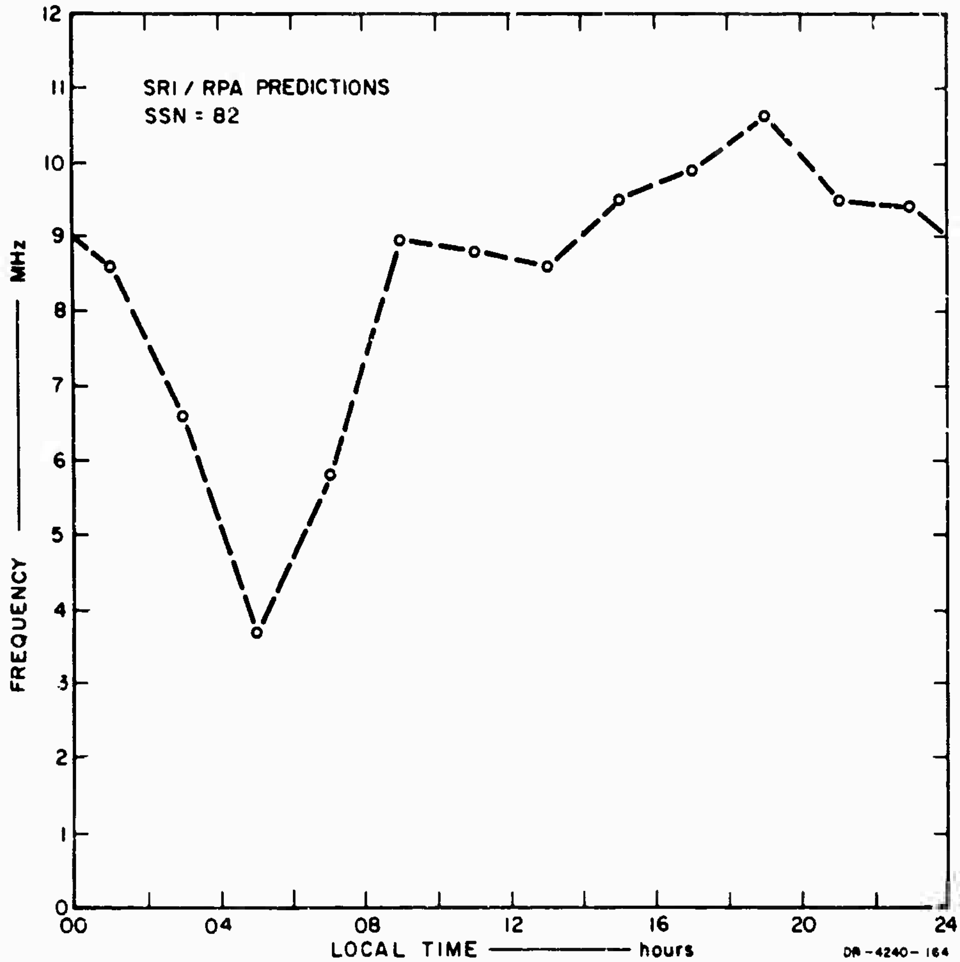

FIG. 7 CORRECTED foF2 PREDICTIONS FOR MARCH 1967

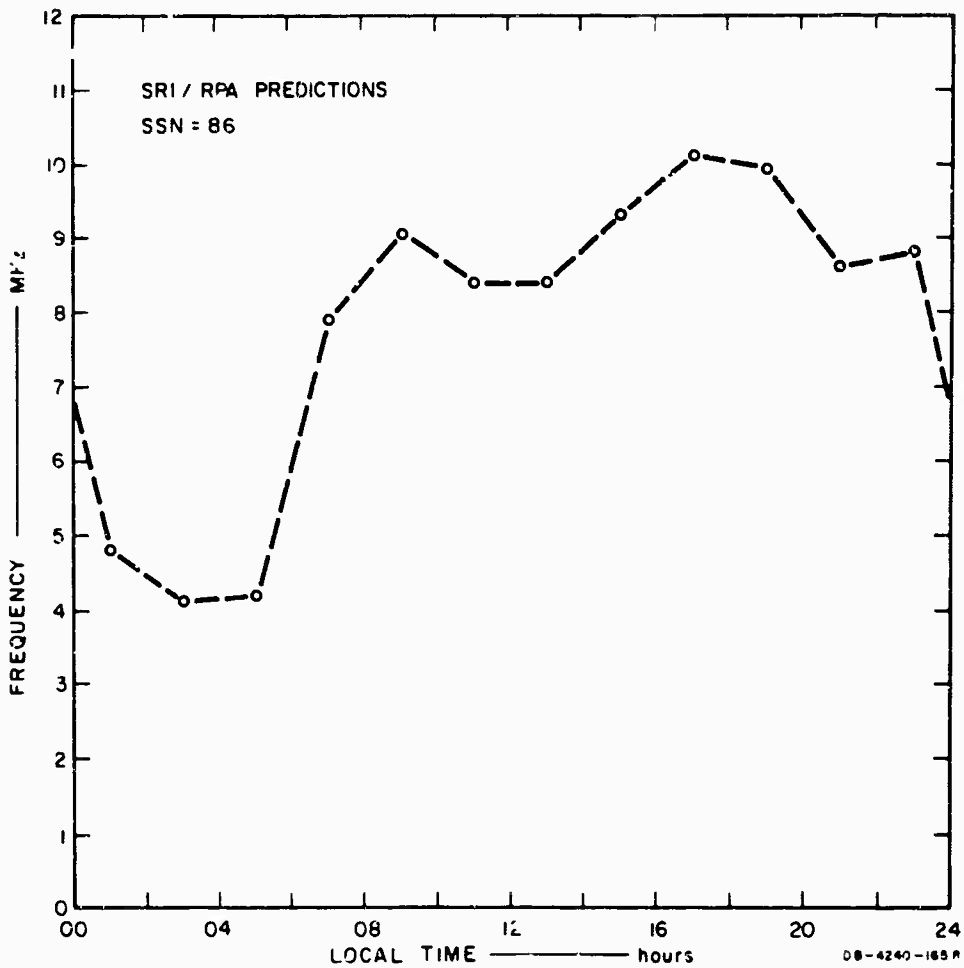

FIG. 8 CORRECTED foF2 PREDICTIONS FOR APRIL 1967

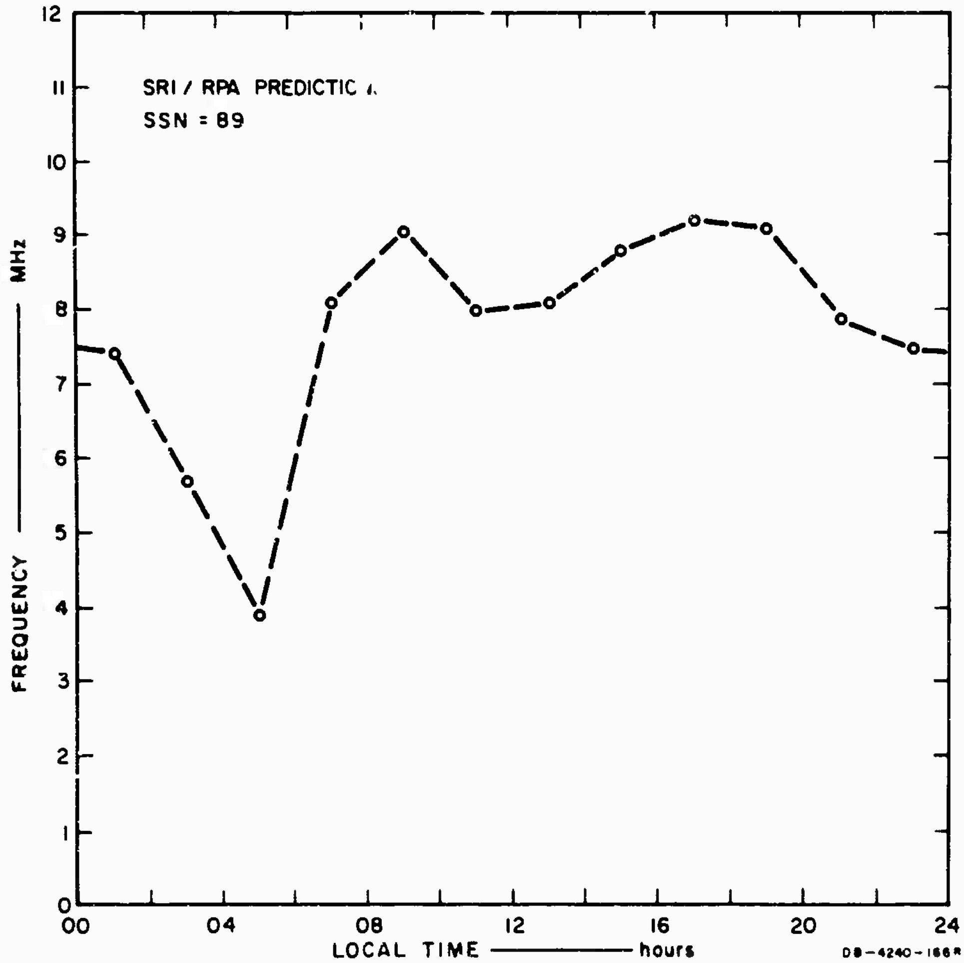

FIG. 9 CORRECTED foF2 PREDICTIONS FOR MAY 1967

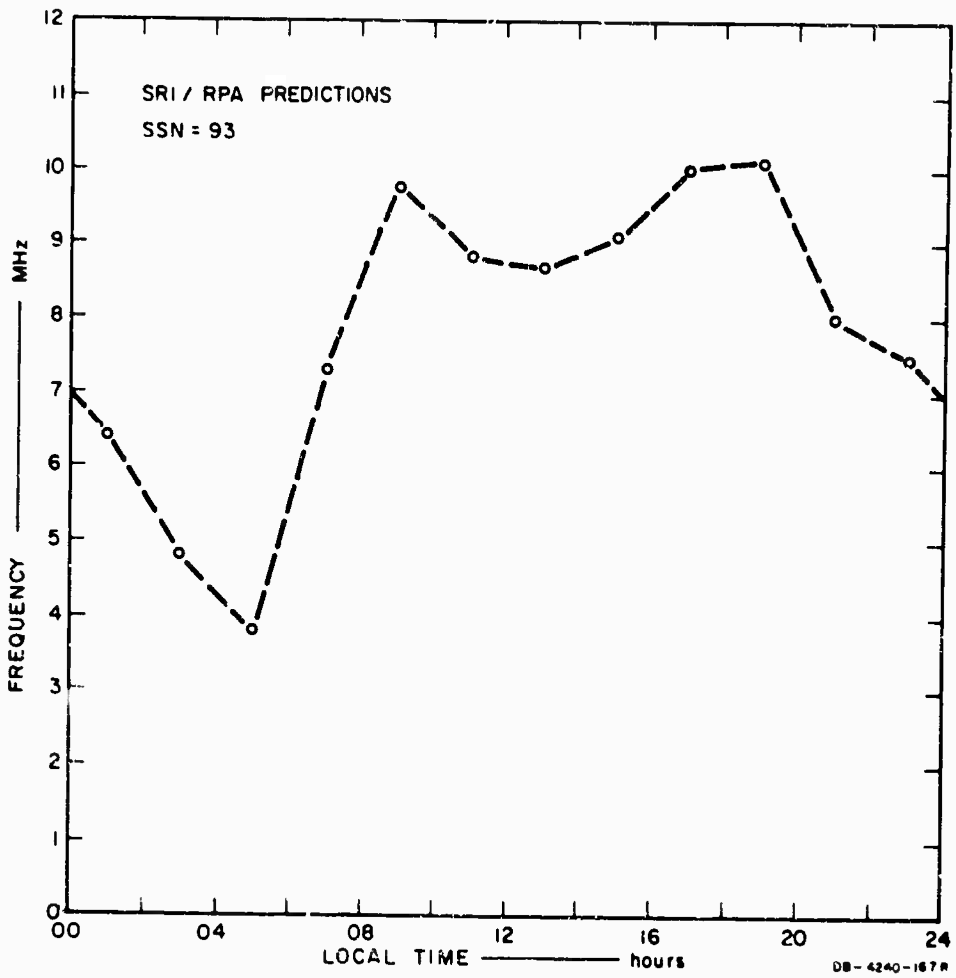

FIG. 10 CORRECTED foF2 PREDICTIONS FOR JUNE 1967

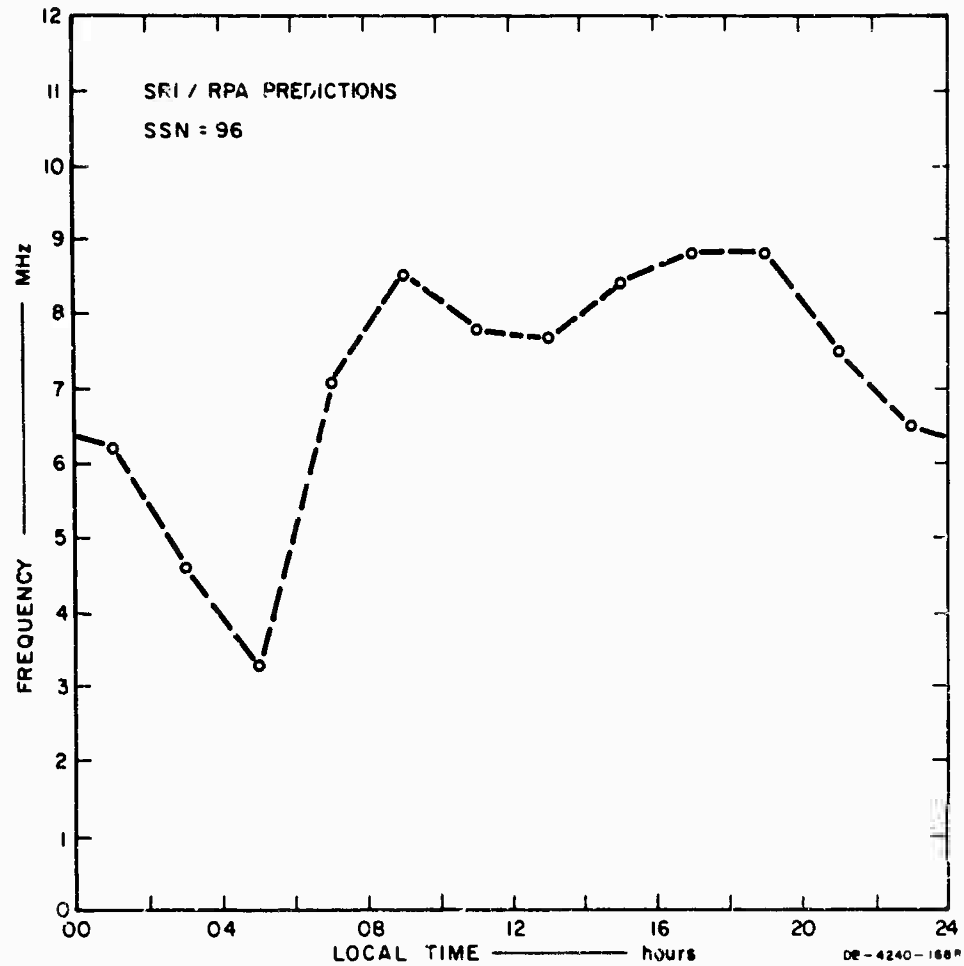

FIG. 11 CORRECTED foF2 PREDICTIONS FOR JULY 1967

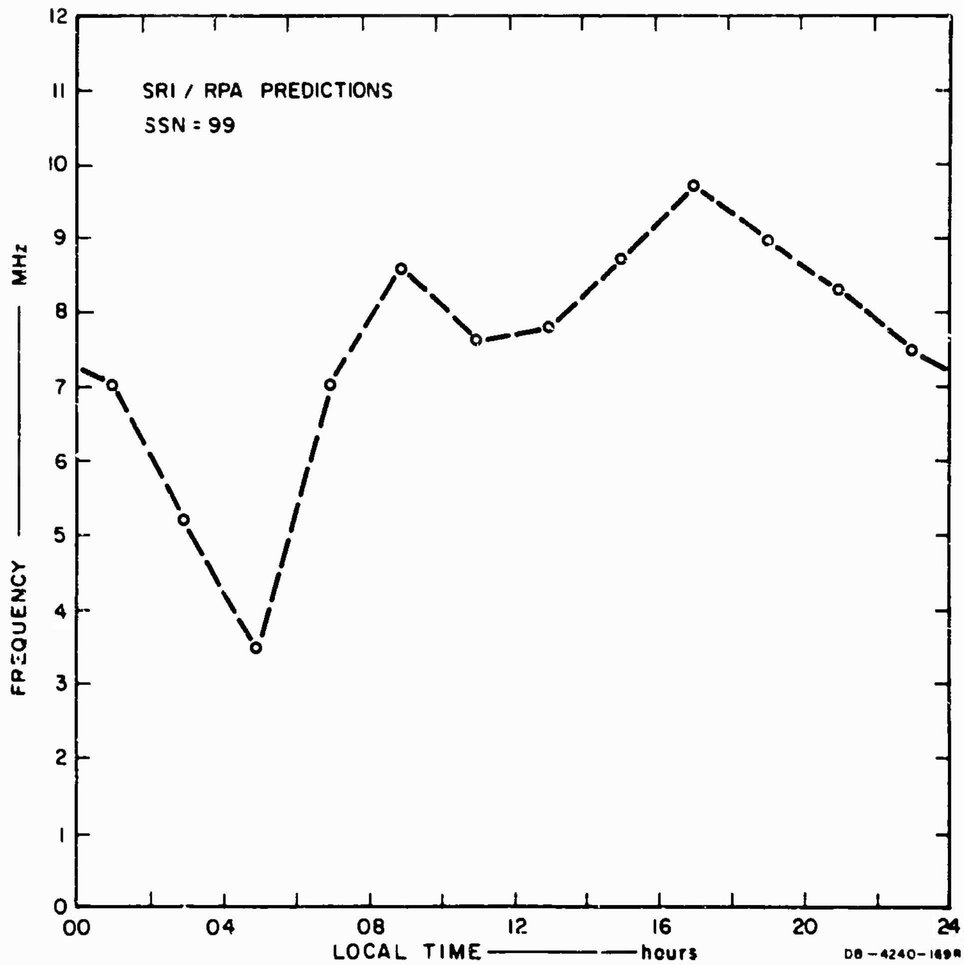

FIG. 12 CORRECTED foF2 PREDICTIONS FOR AUGUST 1967

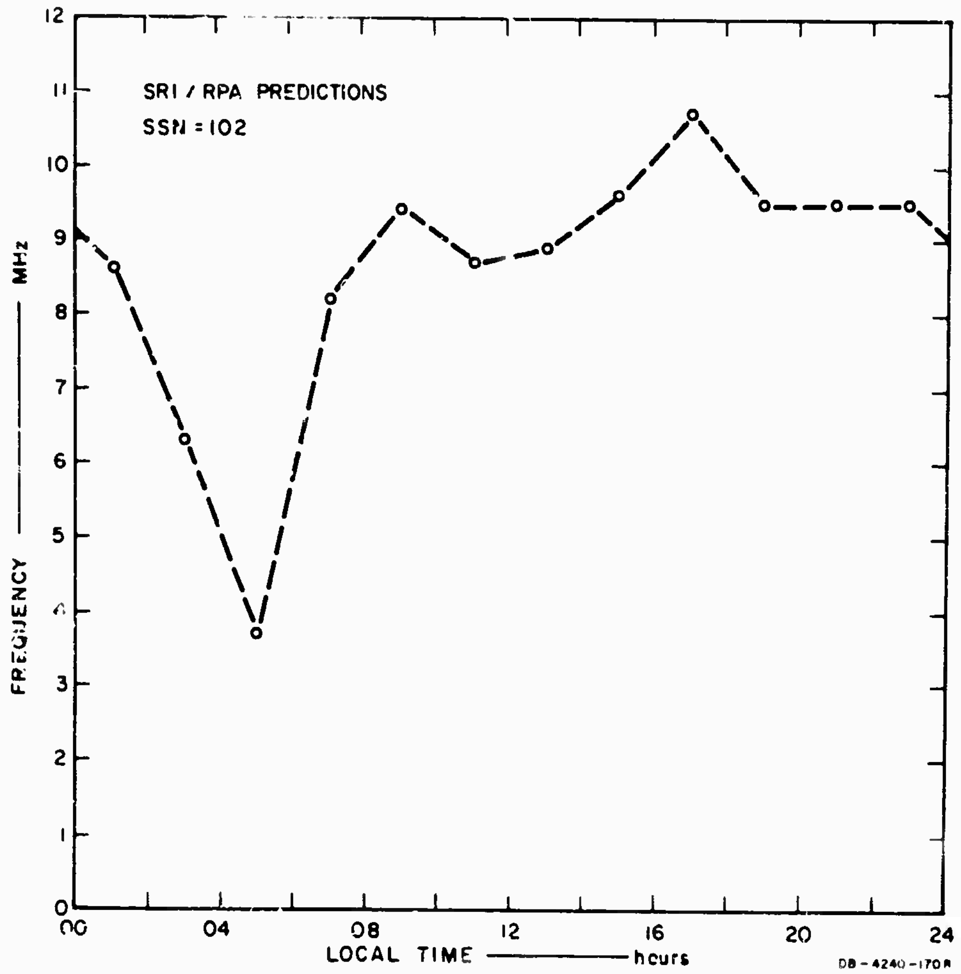

FIG. 13 CORRECTED foF2 PREDICTIONS FOR SEPTEMBER 1967

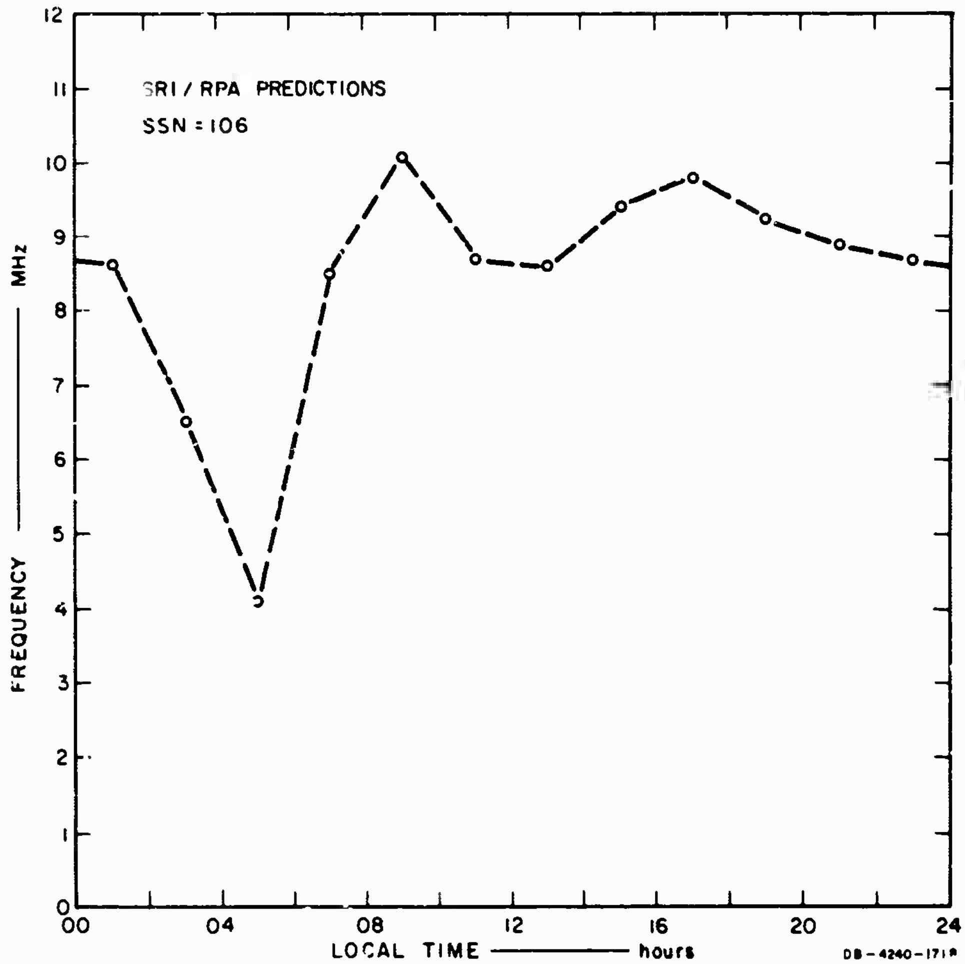

FIG. 14 CORRECTED foF2 PREDICTIONS FOR OCTOBER 1967

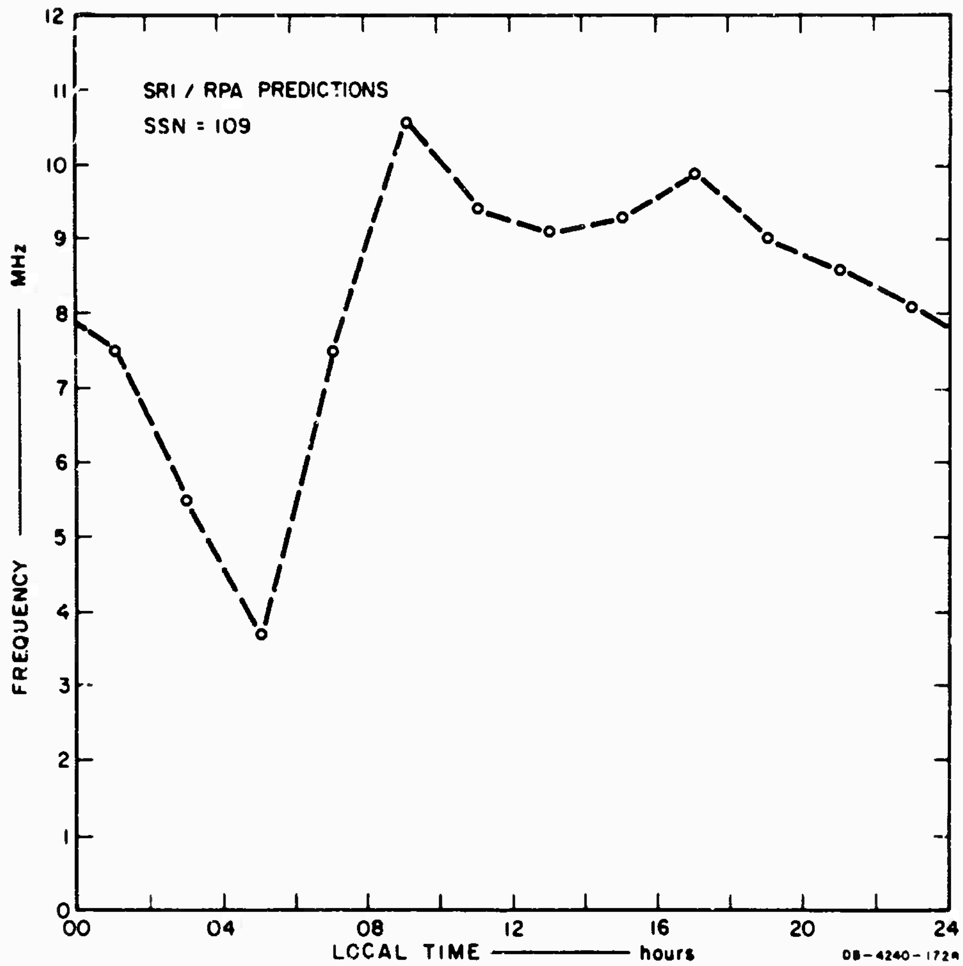

FIG. 15 CORRECTED foF2 PREDICTIONS FOR NOVEMBER 1967

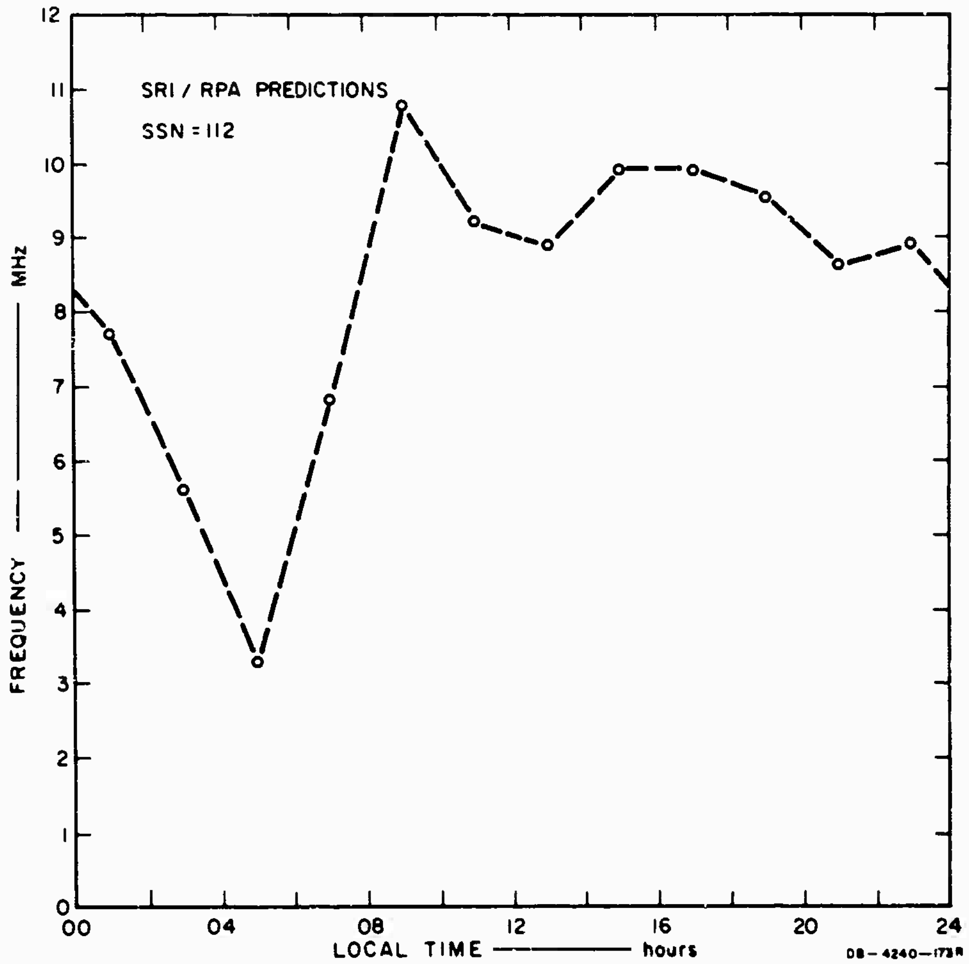

FIG. 16 CORRECTED foF2 PREDICTIONS FOR DECEMBER 1967

These corrected predictions have a minimum in the early morning of 2-4 MHz and a maximum in the afternoon from 9-11 MHz. The predictions average from 6-9 MHz near midnight, decrease to the minimum near 0500 local time, then increase rapidly near sunrise to a broad flat maximum during the daytime and early evening except for a decrease (about 1.0 MHz) near noontime.

IV DISCUSSION

A. EVALUATION

In order to determine the most effective set of predictions, three methods of evaluating the error function were considered. These three techniques are consistent in showing a prediction improvement after the correction is applied. Also, each of the three techniques gives information needed to evaluate the predictions. The first technique, diurnal error function comparison, contains information about both the diurnal and monthly variation of the four median error functions and their quartile ranges. The second technique, mean total error comparison, contains quantitative information independent of local time and allows quick comparison of the prediction schemes. The third technique, distribution error comparison, contains information about the percentages of time that the error is less than a specified amount for the four error functions, also independent of local time.

The first technique gave the most information, since it is the only one that considers the important diurnal variation. The second technique allows quick comparison of the prediction schemes, but only gives one numerical value for each of the four error functions used in a qualitative evaluation. The third technique is also useful in that it is the only technique that gives percentage of time that the error is less than a specified allowable amount.

B. CORRECTED foF2 PREDICTIONS FOR 1967

In developing the 1967 corrected predictions, a choice was necessary between continuing both the SRI/RPA and the NBS predictions or limiting predictions to only one of the prediction methods. The decision was made to use the SRI/RPA method because the correction method must use the same basic computer program and method of obtaining the input data to the program over both the previous and present prediction period, and this could not be readily done with the NBS method. The NBS computer program for the standard predictions has been modified starting with the January

1967 Ionospheric Predictions.[16] Therefore, a correction function based on comparison of 1965-66 data cannot be applied with confidence to 1967 predictions.

An improvement in the 1967 SRI/RPA predictions obtained by applying a correction developed over the previous prediction period, April 1965 through August 1966, is anticipated, comparable, on the average, to the improvement in the SRI/RPA predictions from April 1965 through August 1966 obtained by applying a correction from September 1963 through March 1965. However, the spread in prediction error (quartile range) is expected to increase as the sunspot cycle advances, since the SRI/RPA computer program cannot account for fluctuations in solar activity.

The SRI/RPA standard predictions increased about 1.0 MHz from 1966 to 1967. This prediction increase is caused by the large sunspot number increase (this was the only parameter changed in the computer program). The sunspot numbers used in the SRI/RPA prediction program varied between 33 and 74 for 1966 and between 74 and 112 for 1967.

All predictions discussed in this report apply to vertical paths over Bangkok. Other studies indicate that these predictions may be applied--with decreasing accuracy--over near-vertical paths (0-200 km) in the vicinity of Bangkok. At greater distances, significant corrections may be needed to take into account latitudinal and longitudinal effects.

V CONCLUSIONS AND RECOMMENDATIONS

An important rule when operating a transceiver system via skywave is to choose the operating frequency near the predicted MUF; hence, accurate prediction of MUF becomes vital. The MUF frequency comparison was developed to determine the prediction accuracy and to develop a correction that can be applied to improve future predictions.

The following summarizes the conclusions and recommendations of this research:

(1) The correction functions derived in Ref. 14, when applied to the predictions for 1965-1966, showed a prediction improvement for both the SRI/RPA and NBS predictions. The corrected NBS predictions showed the greatest improvement.

(2) The SRI/RPA standard predictions for 1967 indicate an average increase of 1.0 MHz over the 1966 predictions.

(3) The SRI/RPA corrected predictions for 1967 indicate that an operating frequency up to 8.0 MHz can be used during the daytime and an operating frequency down to 3.0 MHz can be used during the nighttime for near-vertical paths (0-200 km) in the vicinity of Bangkok.

(4) It is recommended that the 1967 predictions be evaluated by comparison with foF2 values observed on the vertical-incidence sounder at Bangkok. It is further recommended that, if the 1967 prediction results of the evaluation show an improvement due to the correction application, then the SRI/RPA corrected predictions for 1968 should be generated using a new correction derived from the 1967 comparison.

(5) It is recommended that the new standard NBS numerical mapping predictions for 1967 be compared with the Bangkok observed values to derive a new correction function that can be applied to the NBS standard predictions for 1968.

(6) It is also recommended that a study be performed to determine if a correction function derived over a shorter period of time can be applied to future standard predictions with a prediction improvement. (The use of a correction function derived over a shorter period of time may be able to take into account possible solar cycle variations of the correction function.) The new standard NBS numerical mapping predictions for both the first month in 1967, the first three months, the first six months, and the first twelve months in 1967 should be compared with the Bangkok observed values to derive a correction function that can be applied to the following months of standard predictions.

Appendix A

SRI/RPA PREDICTION EFFECTIVENESS

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Appendix A

SRI/RPA PREDICTION EFFECTIVENESS

Comparison is made of both standard and corrected SRI/RPA MUF predictions, with vertical incidence ionosonde observations at Bangkok for the period April 1965 through August 1966. These monthly median data are presented chronologically in Figs. A-1 through A-17. The three curves in the upper part of each figure show standard and corrected MUF predictions and observed foF2; the two curves in the lower part of each figure show the prediction error before and after the correction was made.

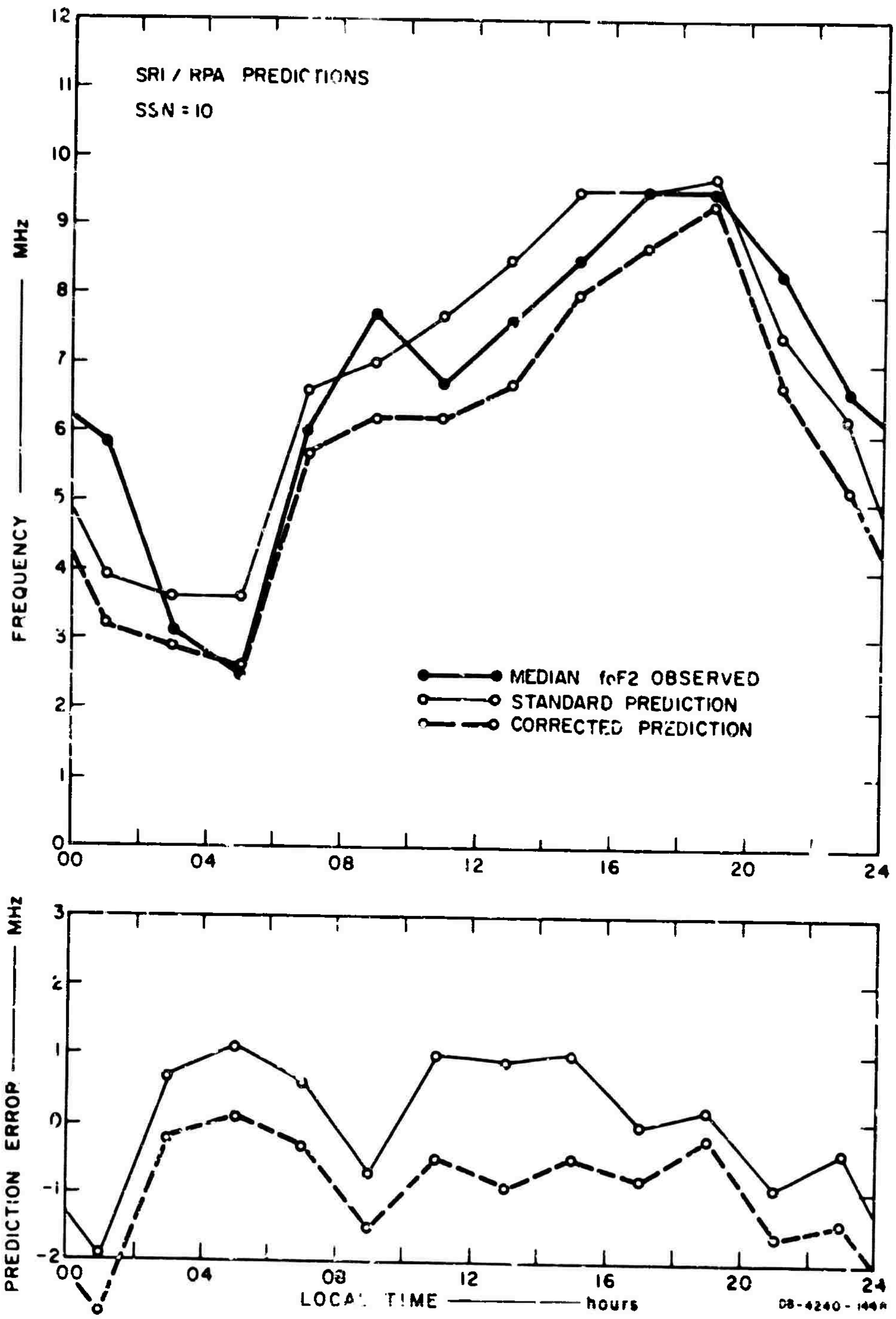

FIG. A-1 COMPARISON OF OBSERVED AND SRI/RPA-PREDICTED MONTHLY MEDIAN foF2 FOR APRIL 1965

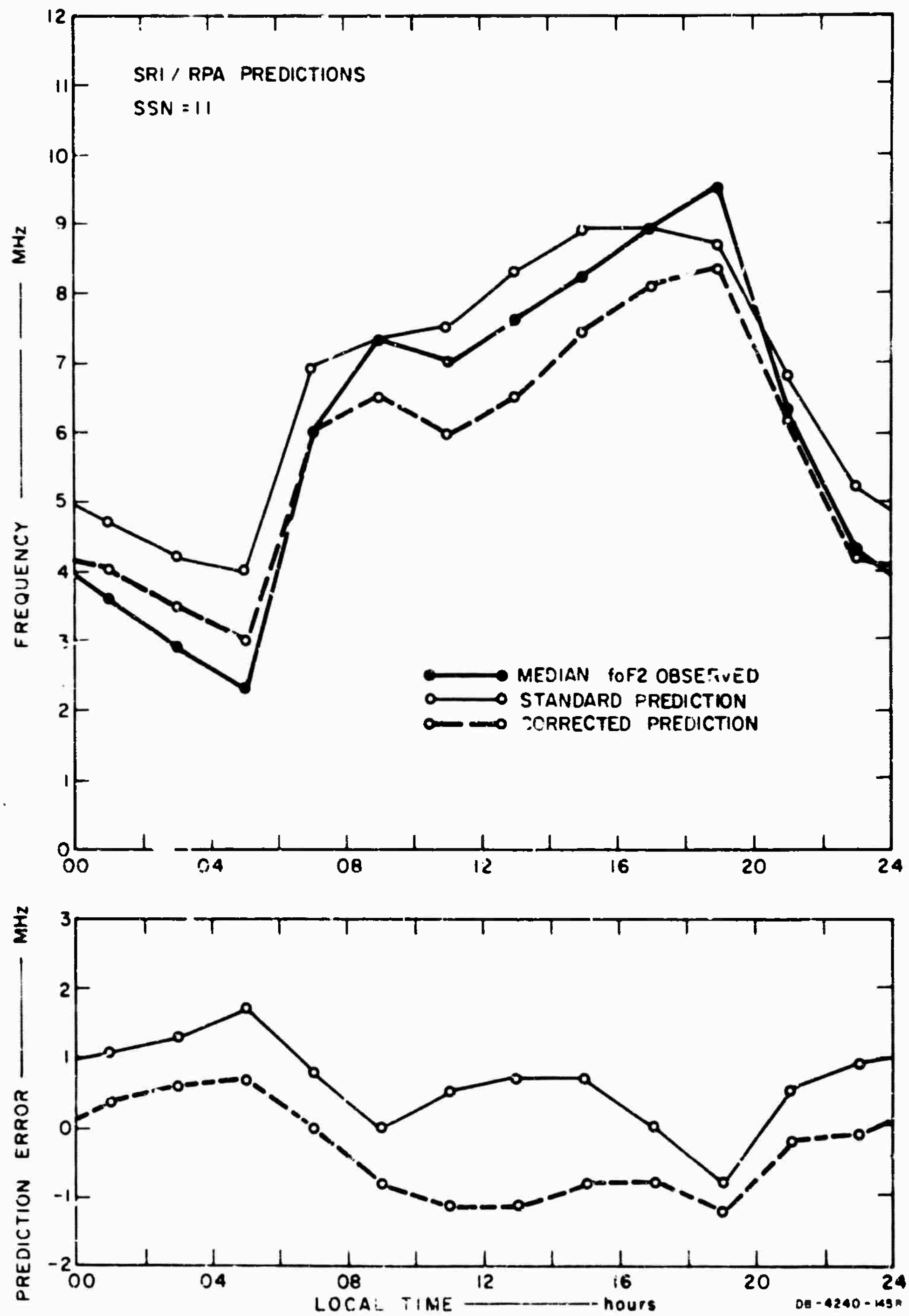

FIG. A-2 COMPARISON OF OBSERVED AND SRI RPA-PREDICTED MONTHLY MEDIAN foF2 FOR MAY 1965

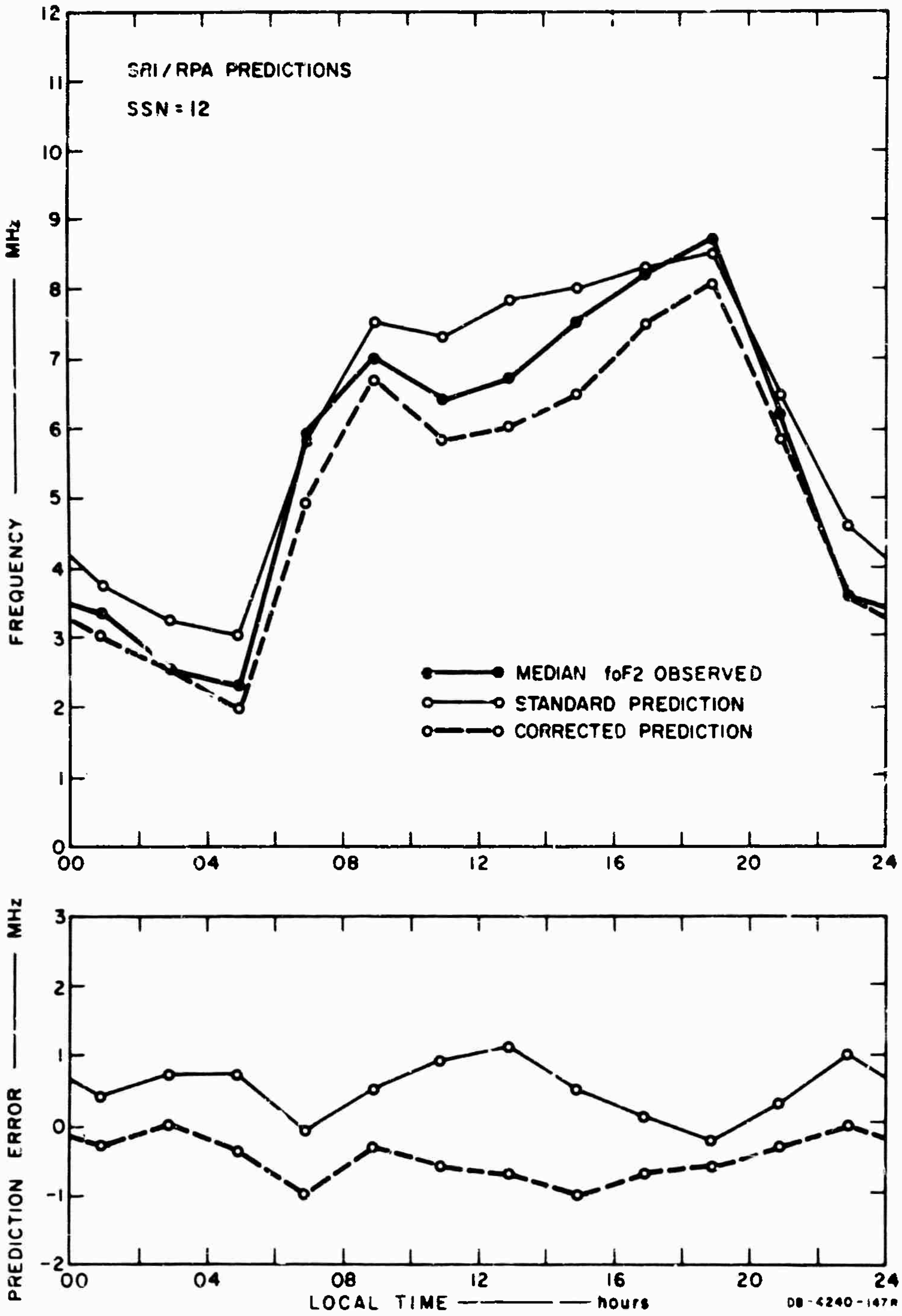

FIG. A-3 COMPARISON OF OBSERVED AND SRI/RPA-PREDICTED MONTHLY MEDIAN foF2 FOR JUNE 1965

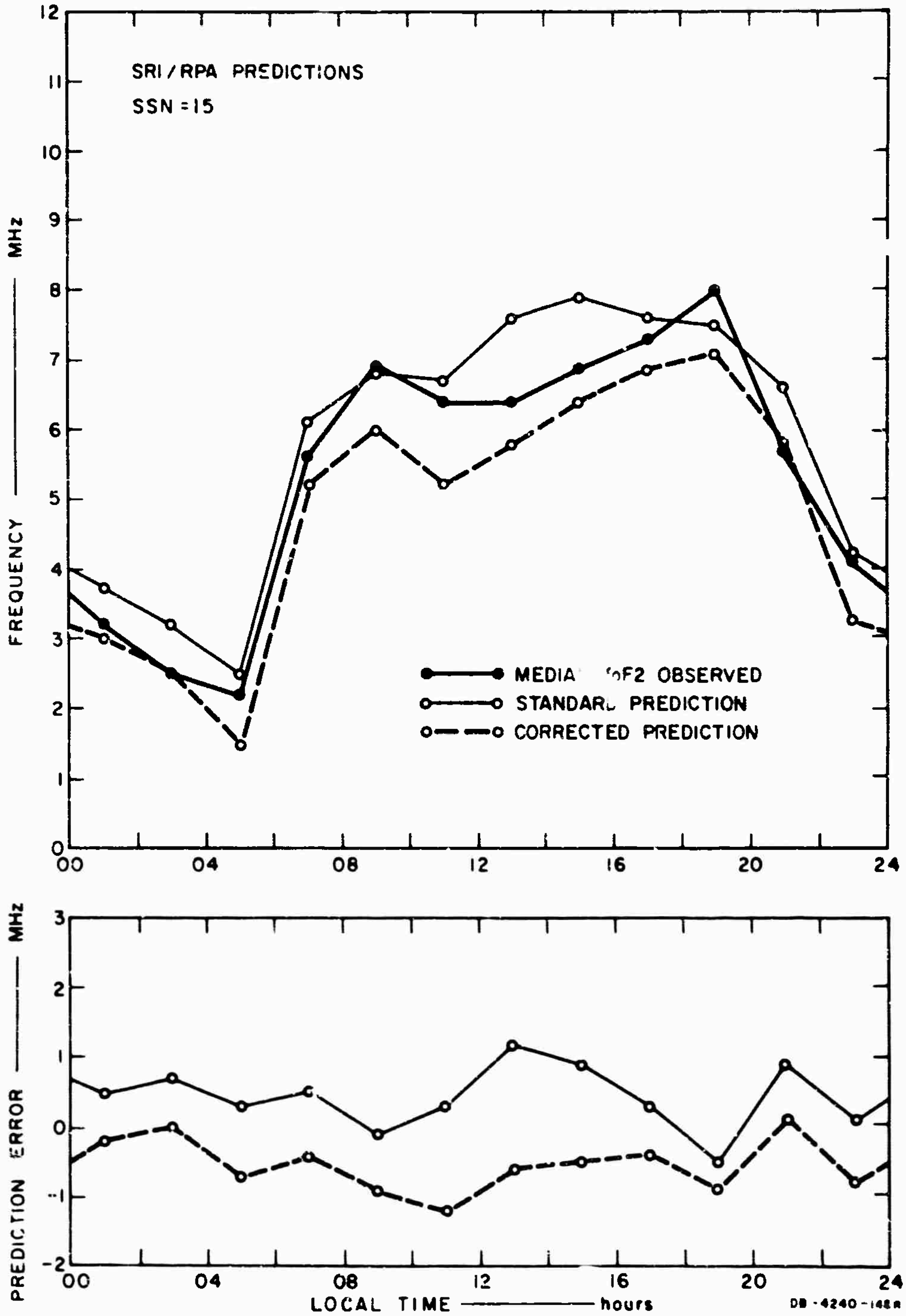

FIG. A-4 COMPARISON OF OBSERVED AND SRI RPA-PREDICTED MONTHLY MEDIAN foF2 FOR JULY 1965

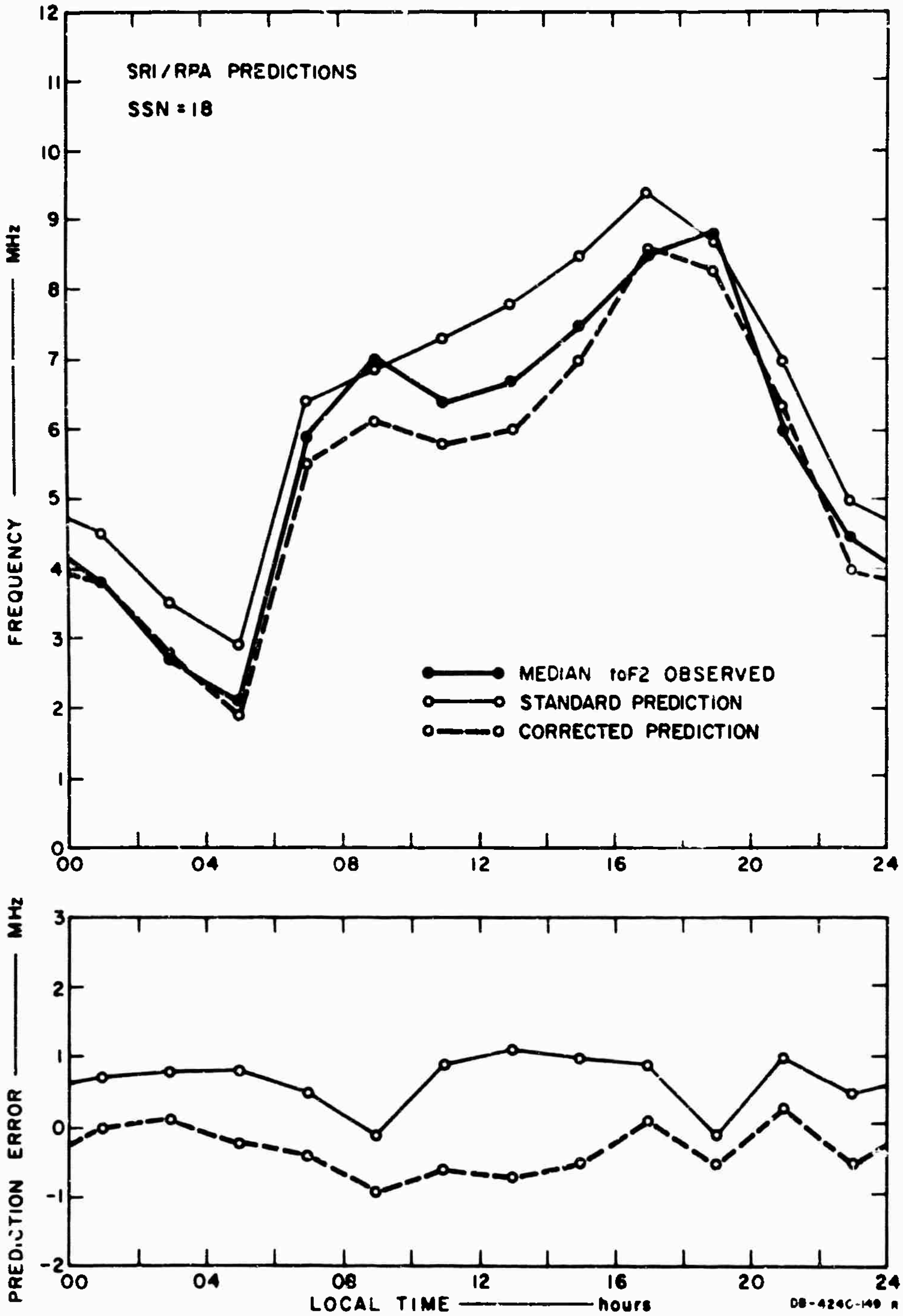

FIG. A-5 COMPARISON OF OBSERVED AND SRI/RPA-PREDICTED MONTHLY MEDIAN foF2 FOR AUGUST 1965

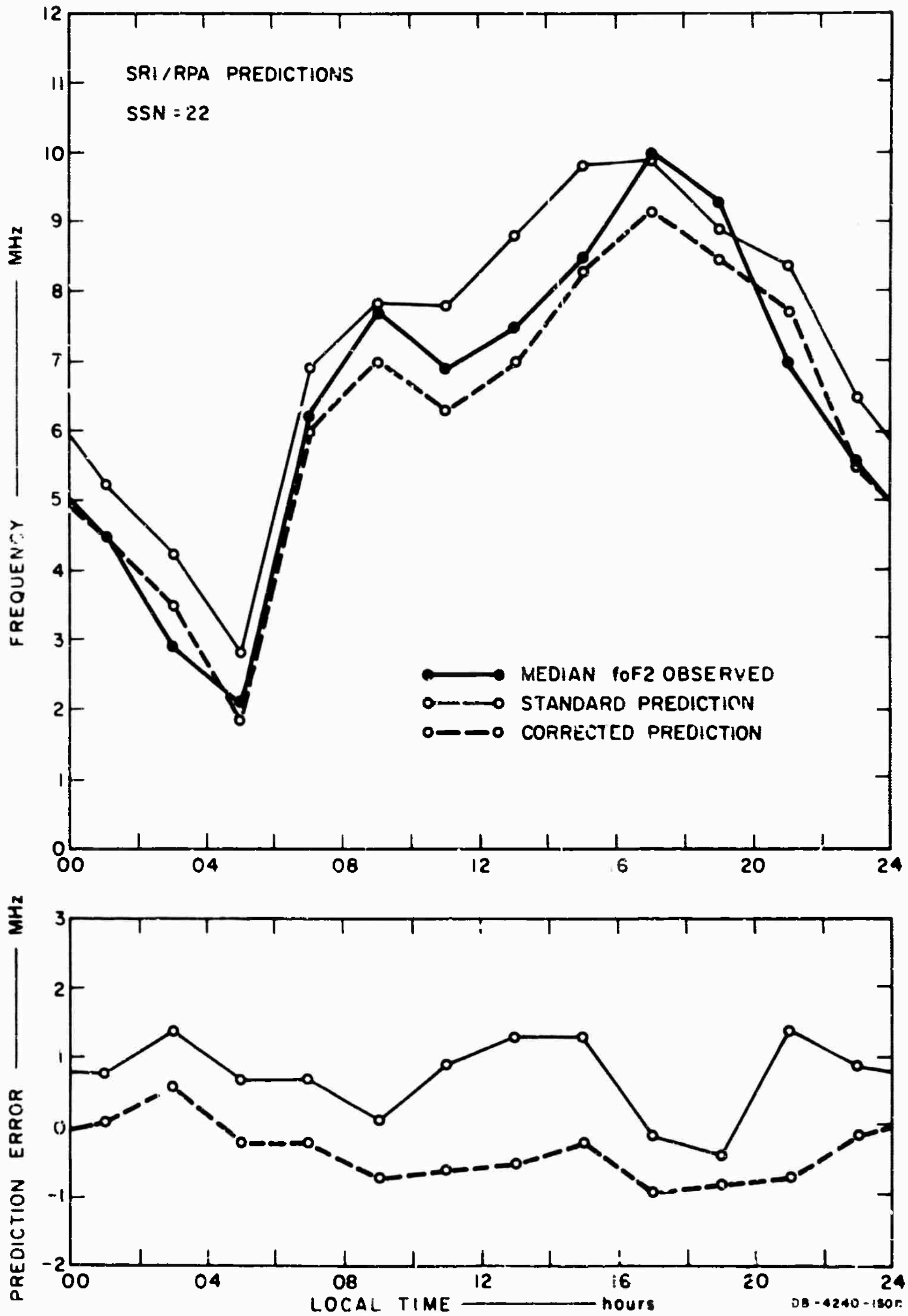

FIG. A-6 COMPARISON OF OBSERVED AND SRI RPA-PREDICTED MONTHLY MEDIAN foF2 FOR SEPTEMBER 1965

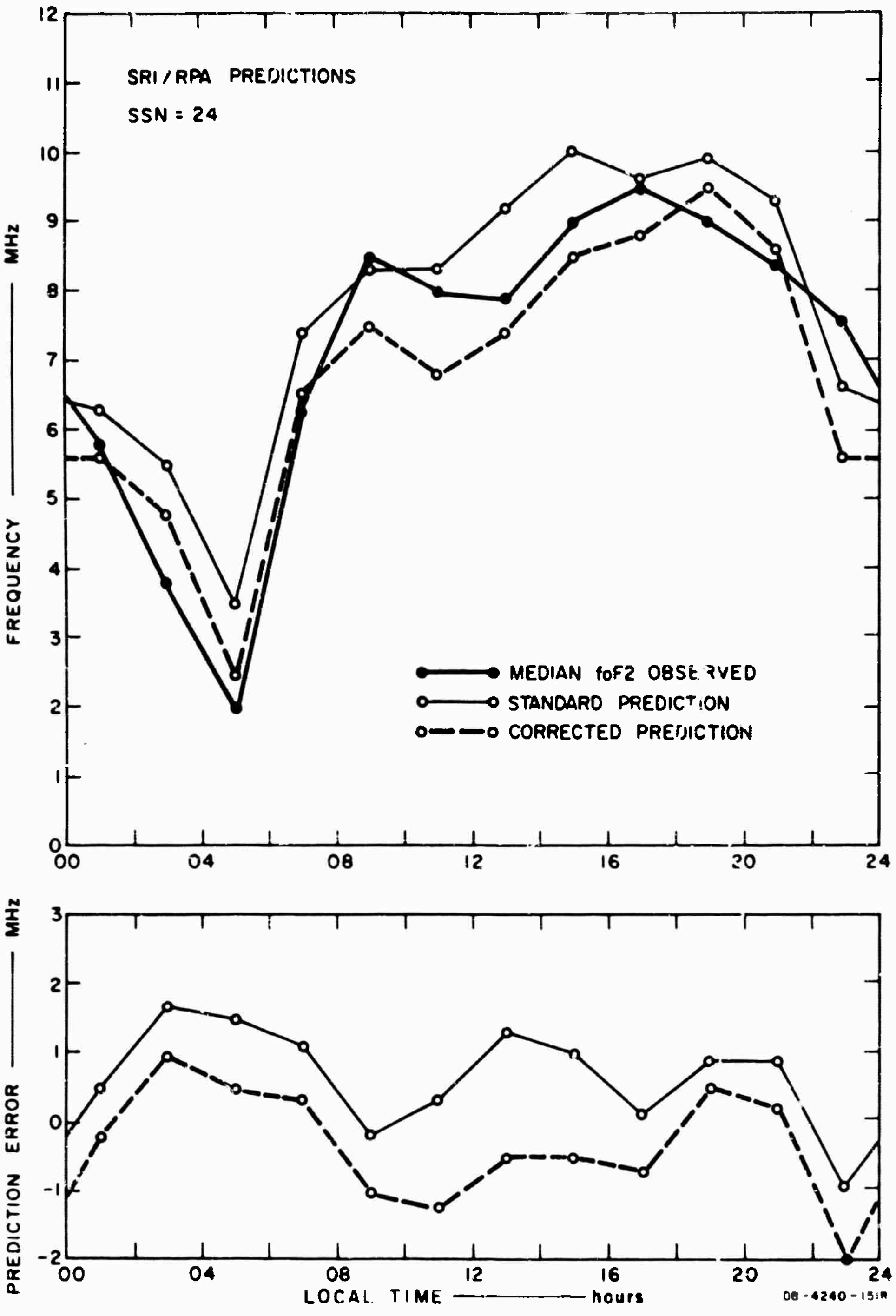

FIG. A-7 COMPARISON OF OBSERVED AND SRI RPA-PREDICTED MONTHLY MEDIAN foF2 FOR OCTOBER 1965

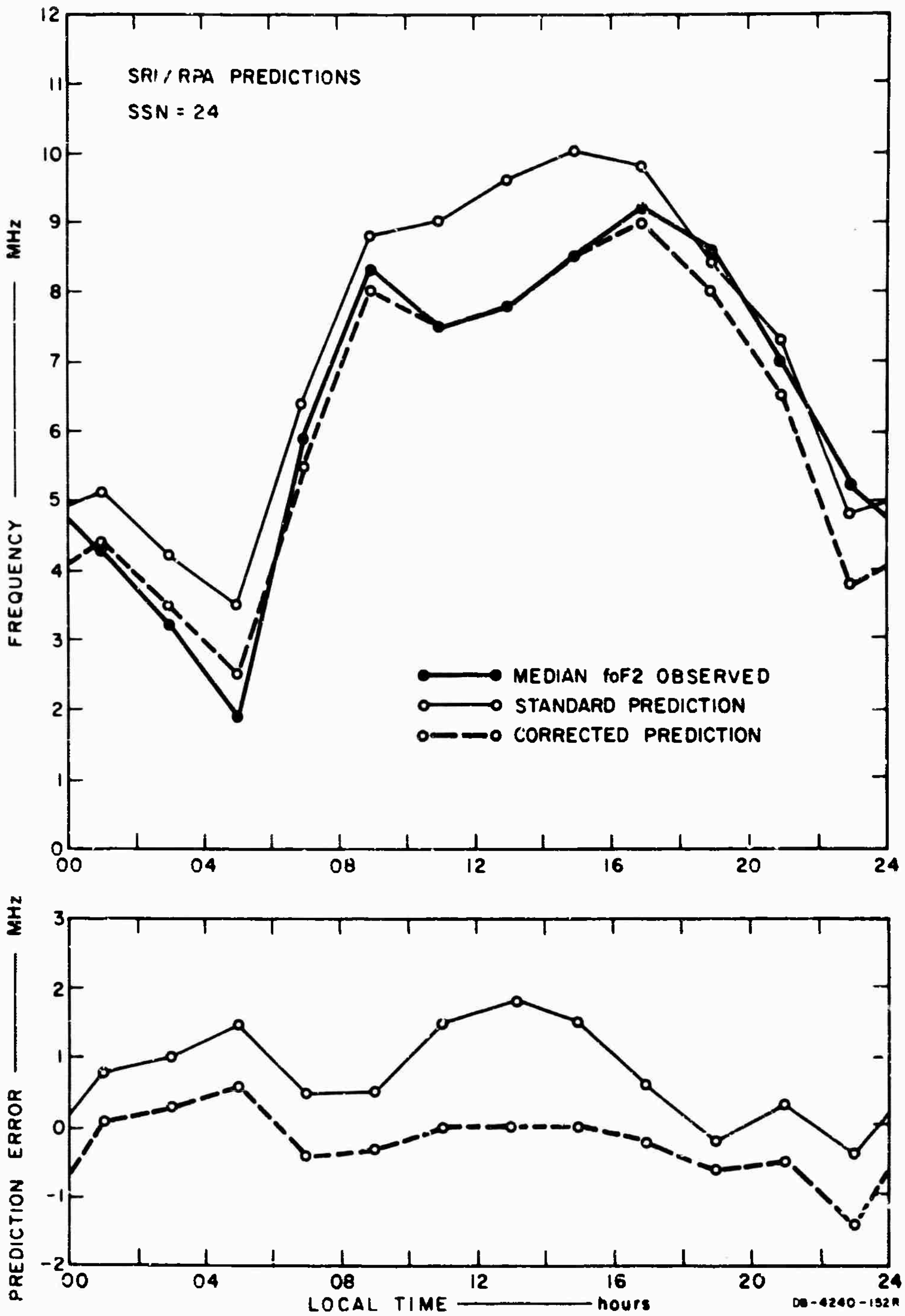

FIG. A-8 COMPARISON OF OBSERVED AND SRI/RPA-PREDICTED MONTHLY MEDIAN foF2 FOR NOVEMBER 1965

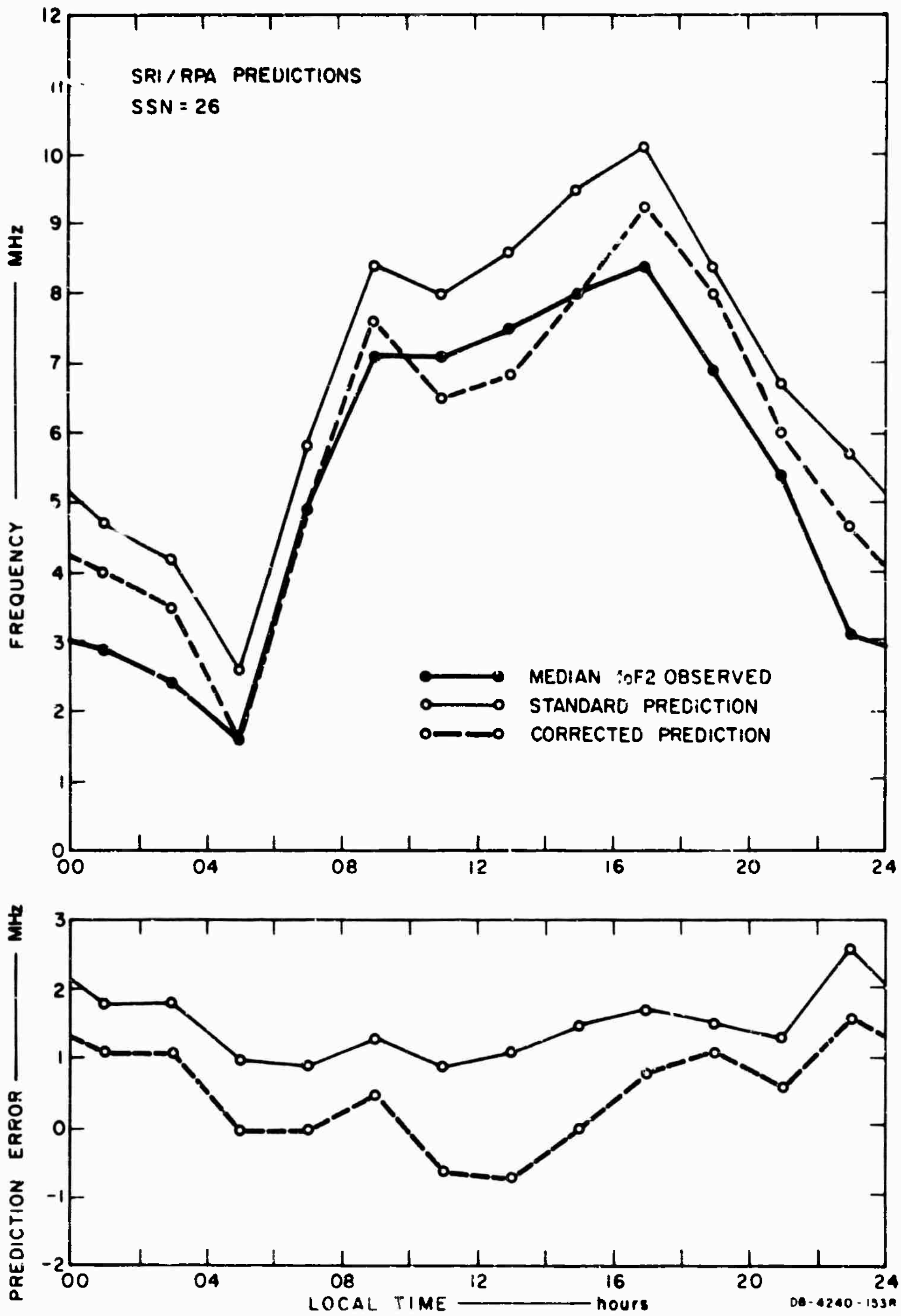

FIG. A-9 COMPARISON OF OBSERVED AND SRI/RPA-PREDICTED MONTHLY MEDIAN foF2 FOR DECEMBER 1965

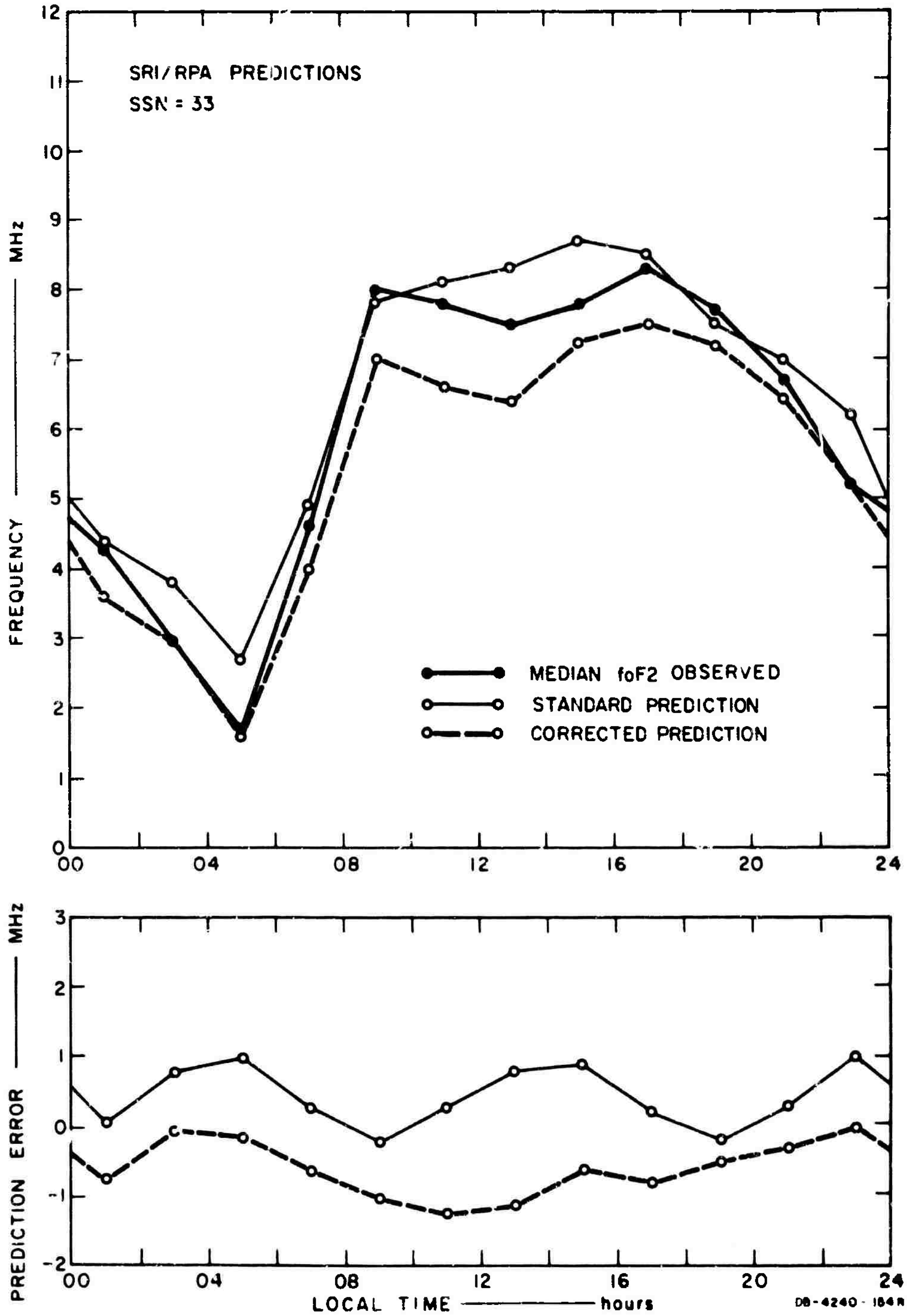

FIG. A-10 COMPARISON OF OBSERVED AND SRI/RPA-PREDICTED MONTHLY MEDIAN foF2 FOR JANUARY 1966

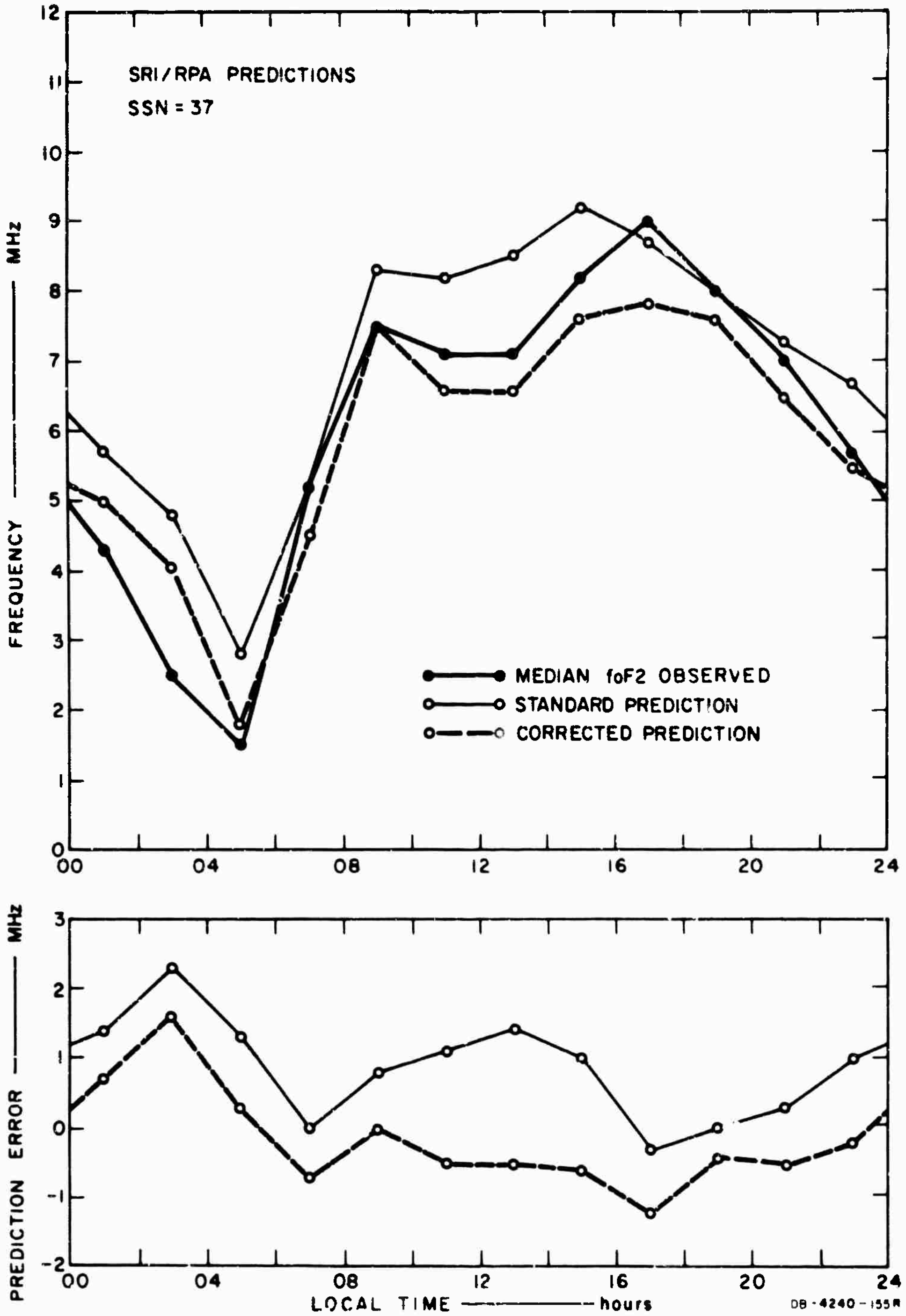

FIG. A-11 COMPARISON OF OBSERVED AND SRI/RPA-PREDICTED MONTHLY MEDIAN foF2 FOR FEBRUARY 1966

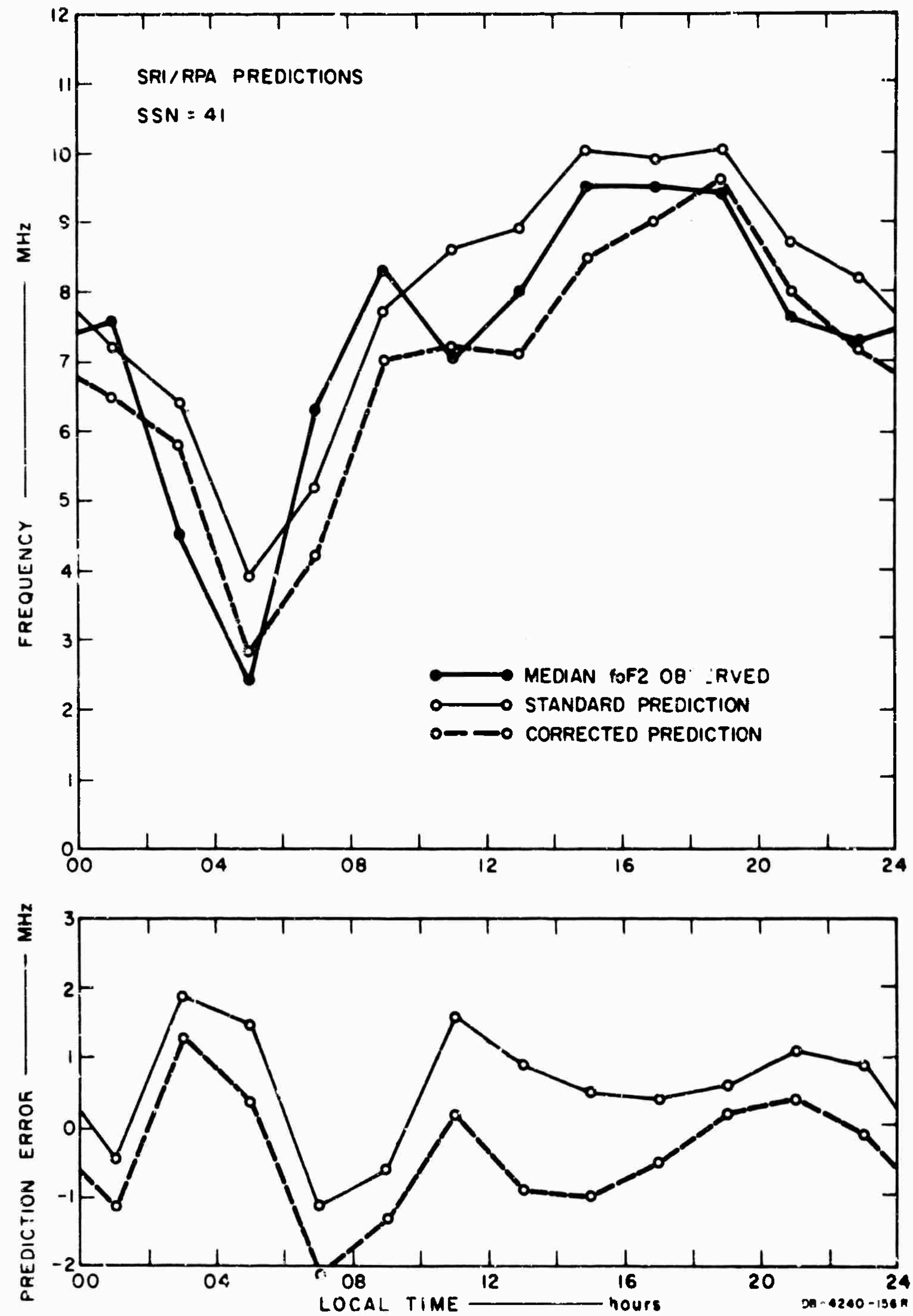

FIG. A-12 COMPARISON OF OBSERVED AND SRI RPA-PREDICTED MONTHLY MEDIAN foF2 FOR MARCH 1966

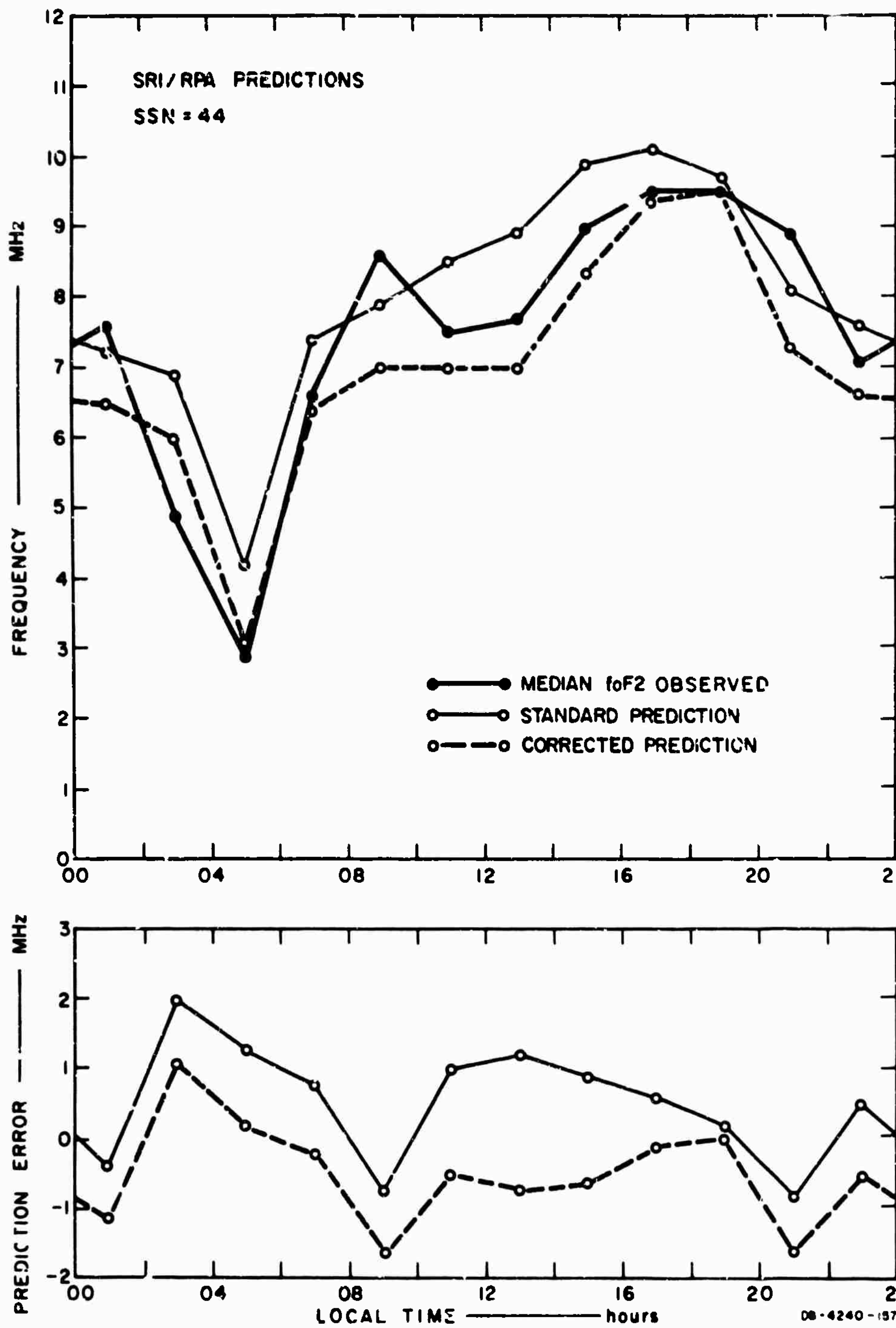

FIG. A-13 COMPARISON OF OBSERVED AND SRI/RPA-PREDICTED MONTHLY MEDIAN foF2 FOR APRIL 1966

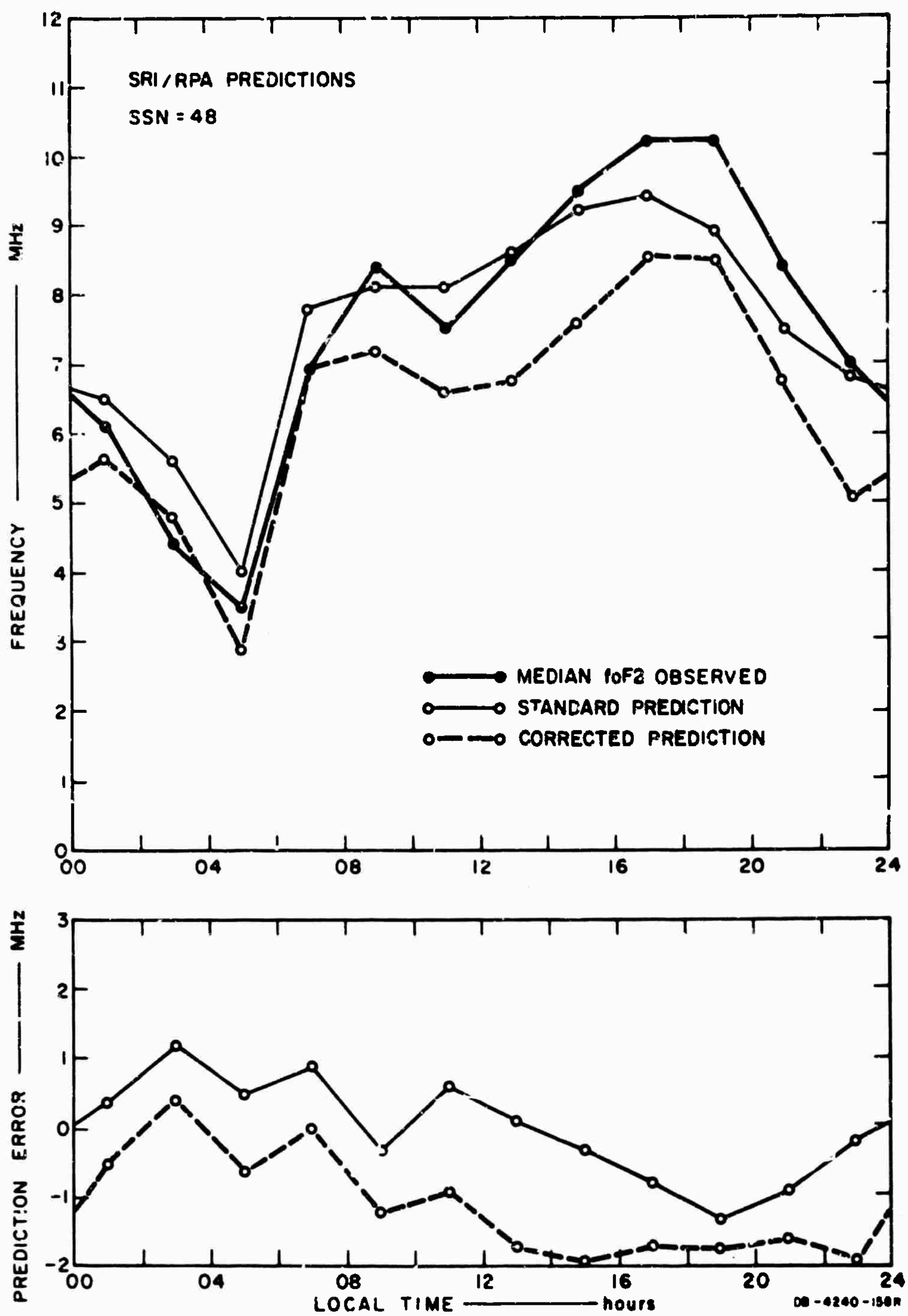

FIG. A-14 COMPARISON OF OBSERVED AND SRI/RPA-PREDICTED MONTHLY MEDIAN foF2 FOR MAY 1966

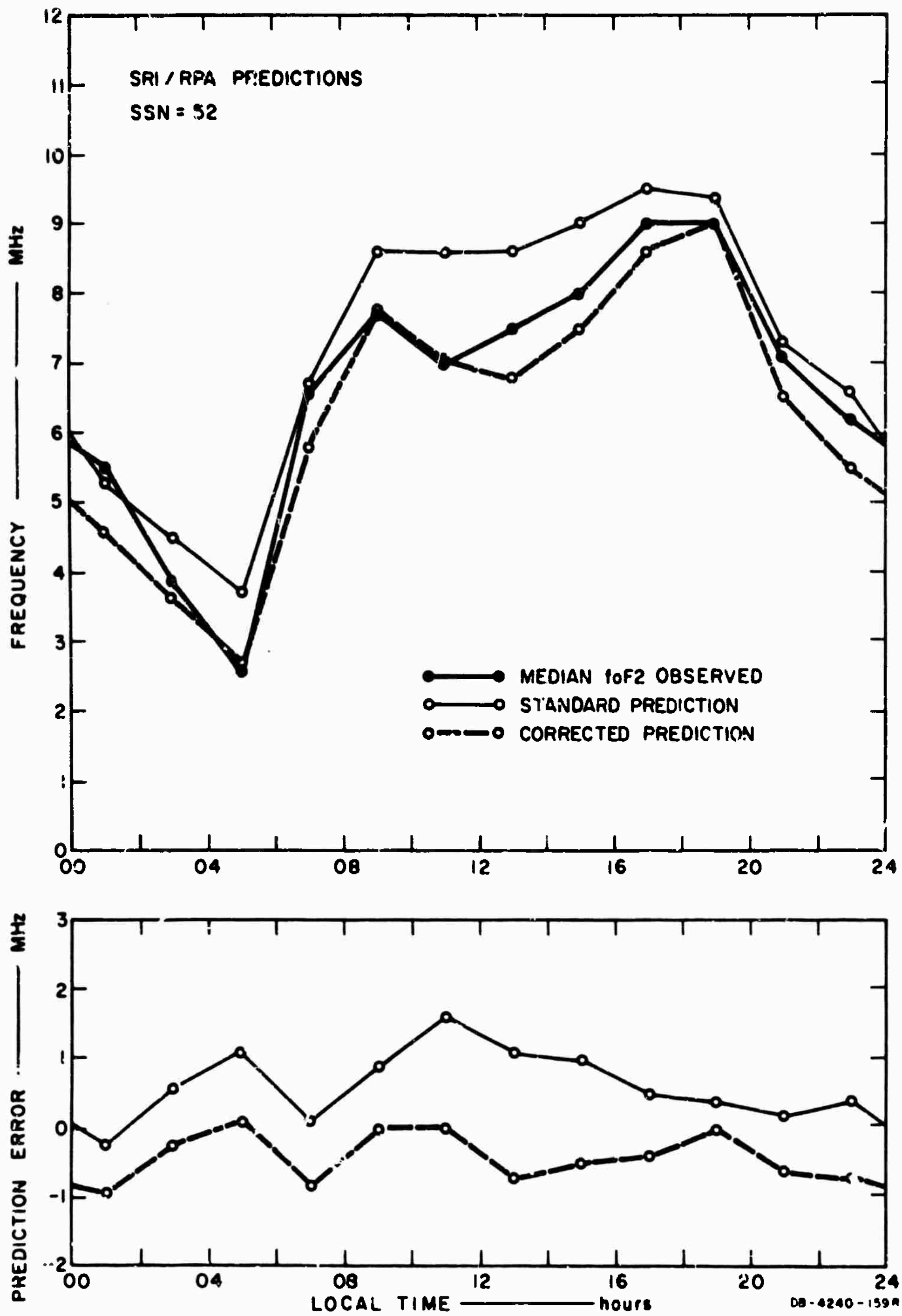

FIG. A-15 COMPARISON OF OBSERVED AND SRI/RPA-PREDICTED MONTHLY MEDIAN foF2 FOR JUNE 1966

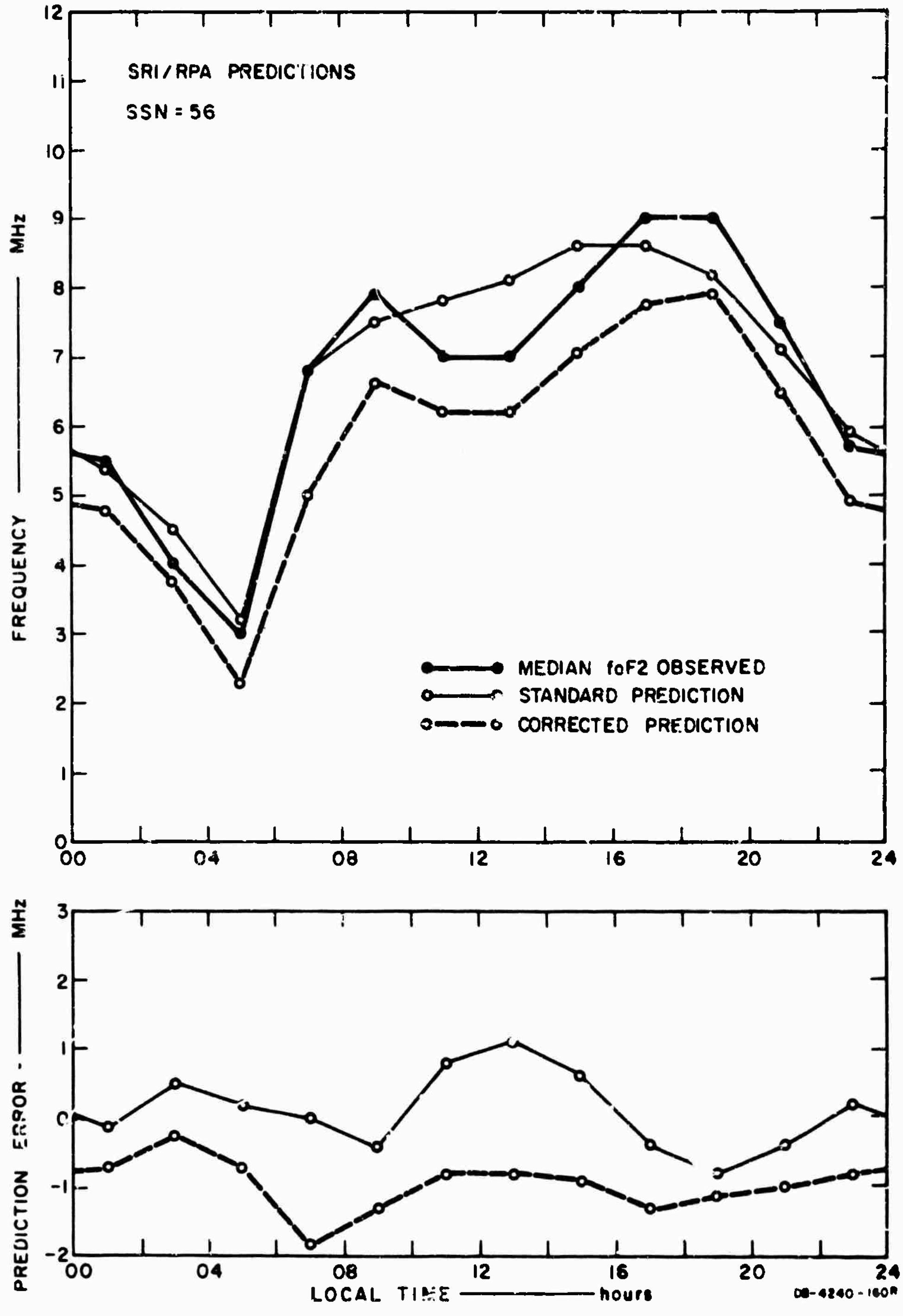

FIG. A-16 COMPARISON OF OBSERVED AND SRI/RPA-PREDICTED MONTHLY MEDIAN foF2 FOR JULY 1966

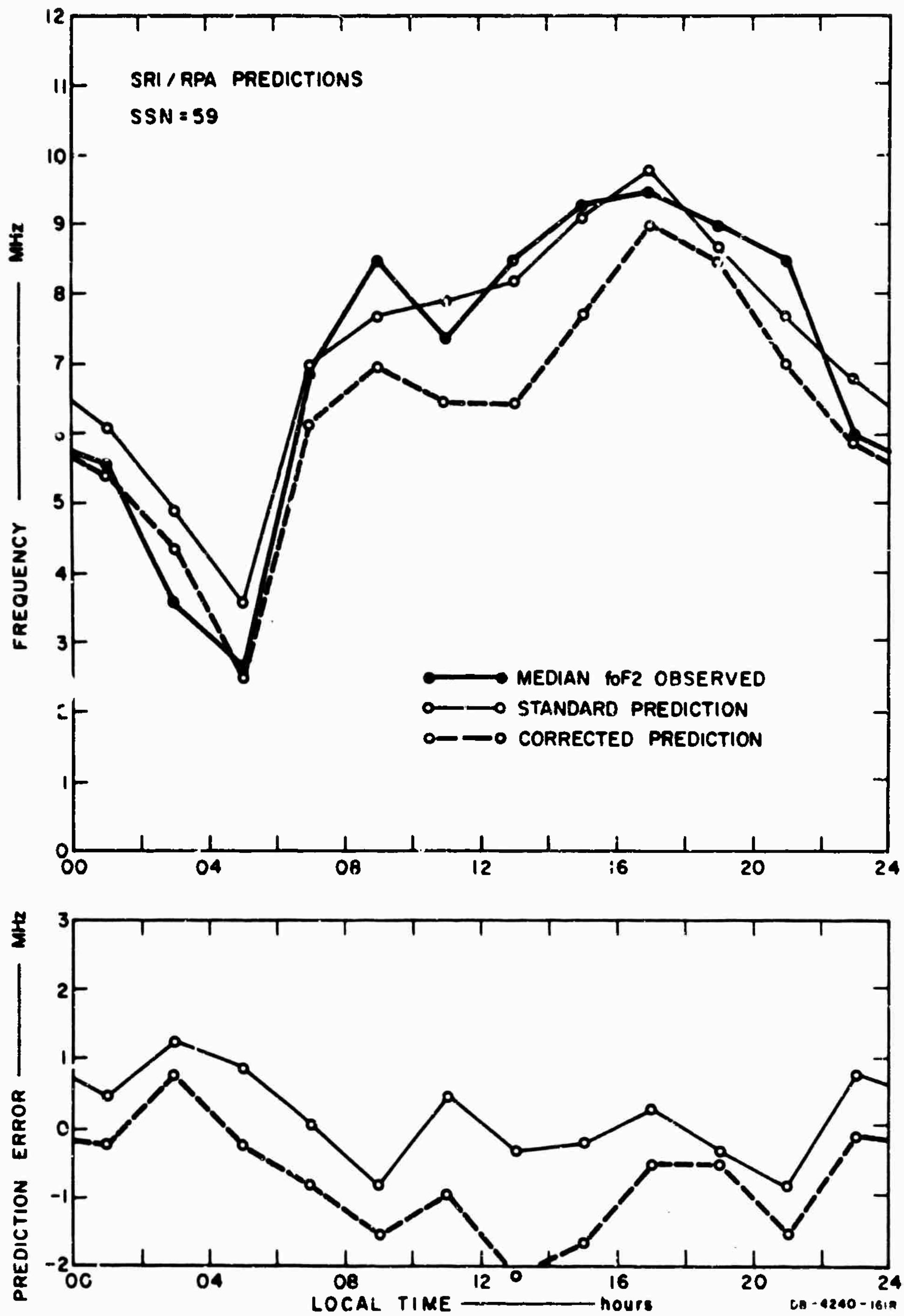

FIG. A-17 COMPARISON OF OBSERVED AND SRI/RPA-PREDICTED MONTHLY MEDIAN foF2 FOR AUGUST 1966

Appendix B

NBS PREDICTION EFFECTIVENESS

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Appendix B

NBS PREDICTION EFFECTIVENESS

Comparison is made of both standard and corrected NBS MUF predictions with vertical incidence ionosonde observations at Bangkok for the period April 1965 through December 1965. These monthly median data are presented chronologically in Figs. B-1 through B-9. The three curves in the upper part of each figure show standard and corrected NBS predictions and observed foF2; the two lower curves show the prediction error before and after the correction was made.

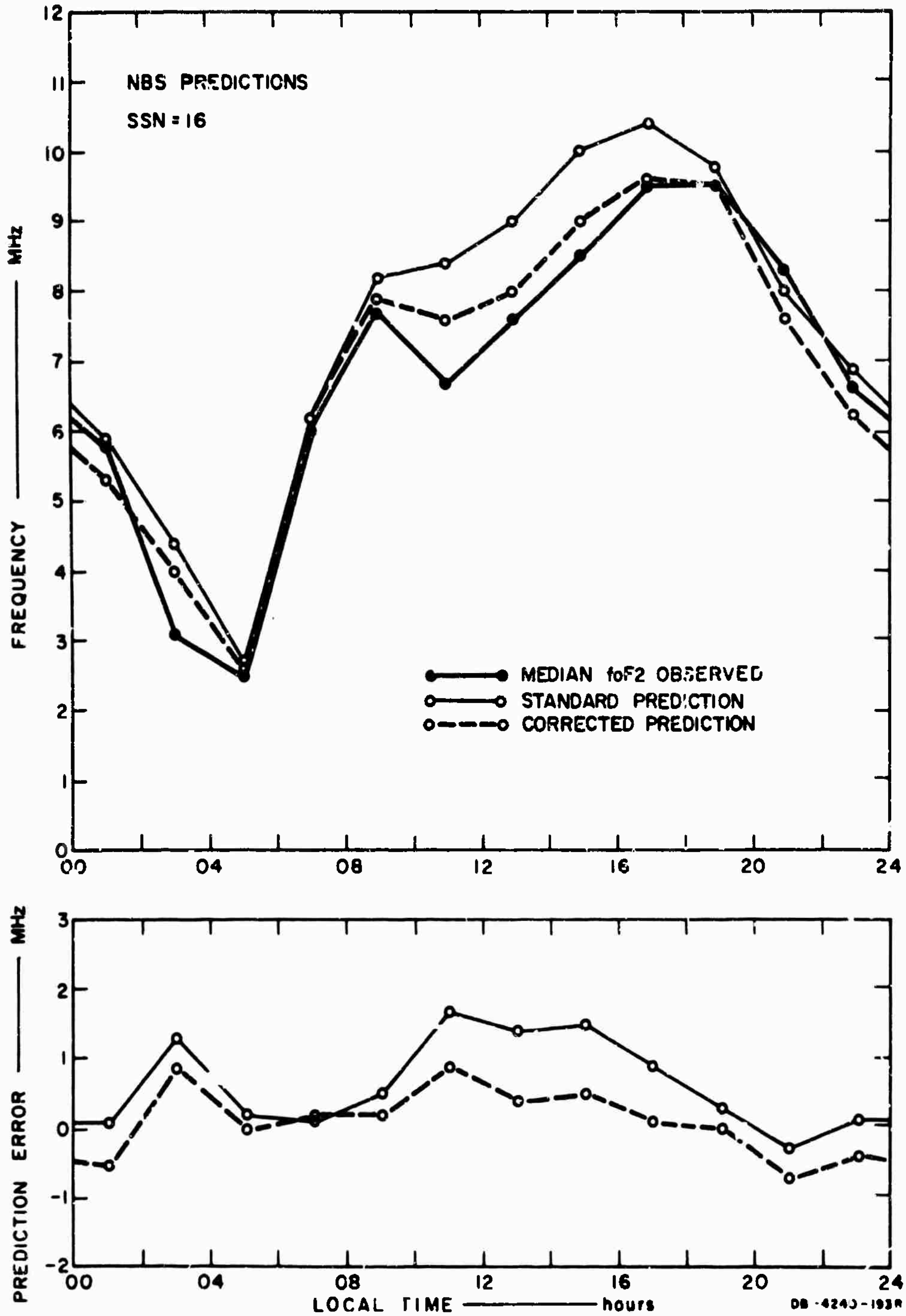

FIG. B-1 COMPARISON OF OBSERVED AND NBS-PREDICTED MONTHLY MEDIAN foF2 FOR APRIL 1965

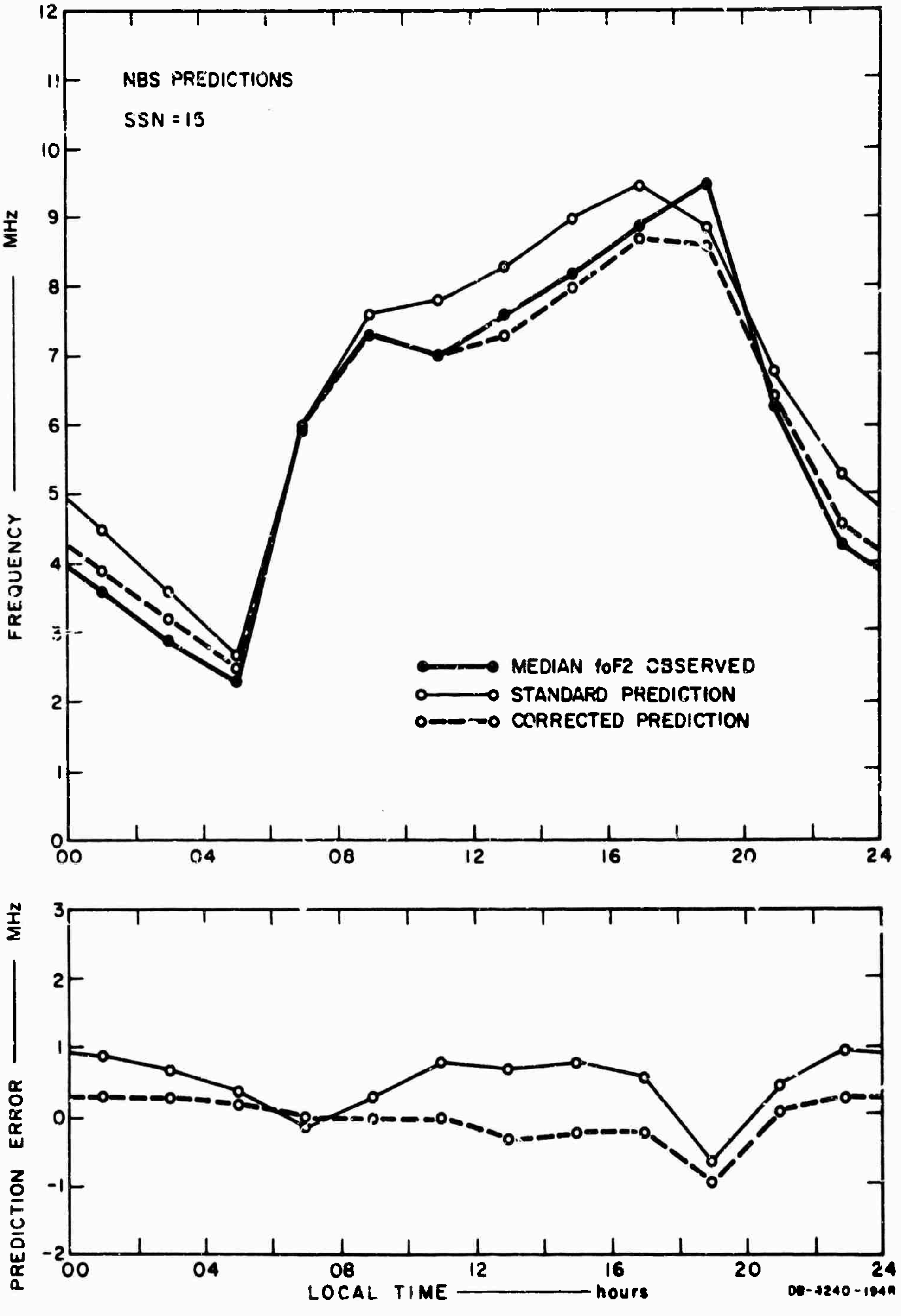

FIG. B-2 COMPARISON OF OBSERVED AND NBS-PREDICTED MONTHLY MEDIAN foF2 FOR MAY 1965

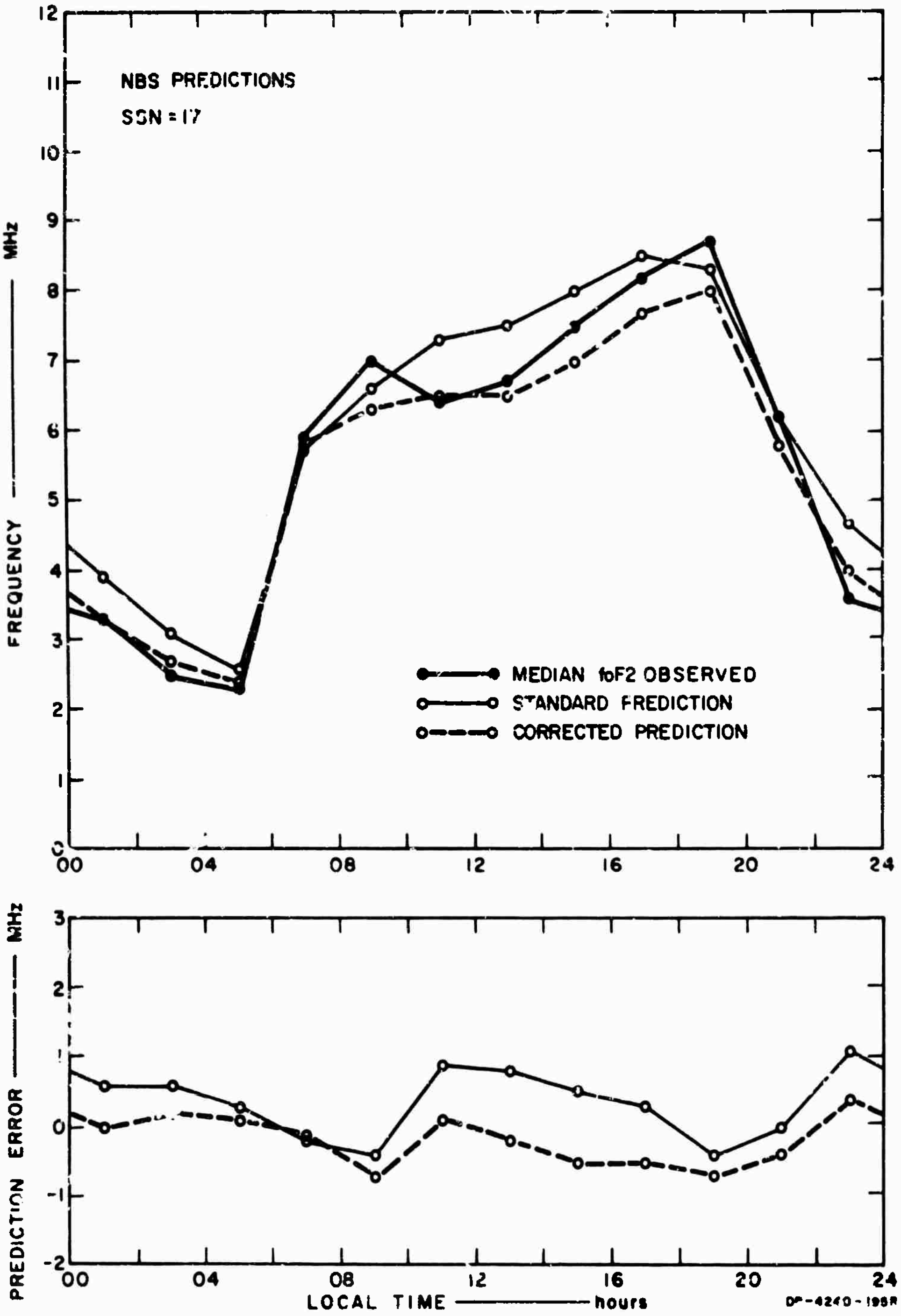

FIG. B-3 COMPARISON OF OBSERVED AND NBS-PREDICTED MONTHLY MEDIAN foF2 FOR JUNE 1965

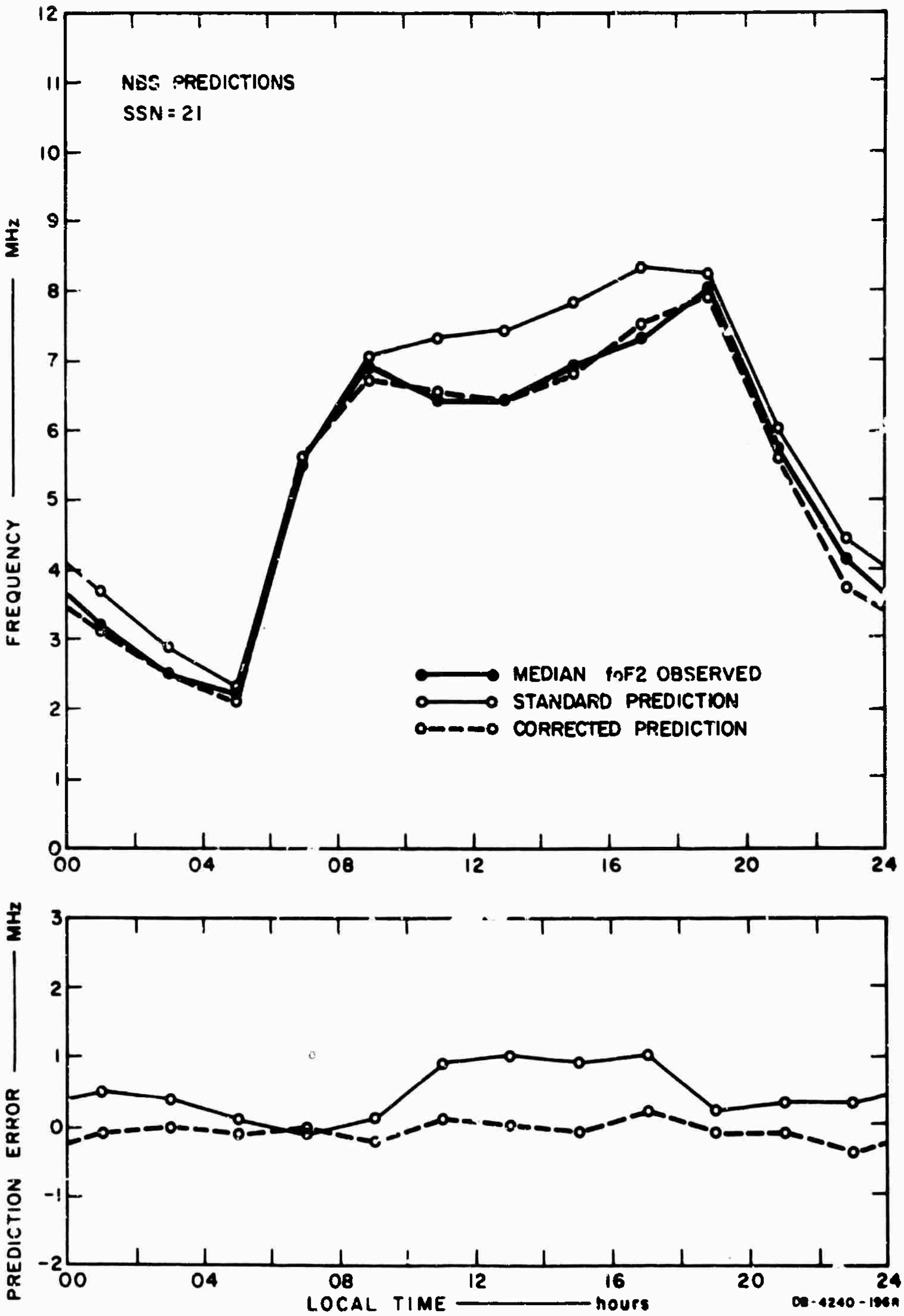

FIG. B-4 COMPARISON OF OBSERVED AND NBS-PREDICTED MONTHLY MEDIAN foF2 FOR JULY 1965

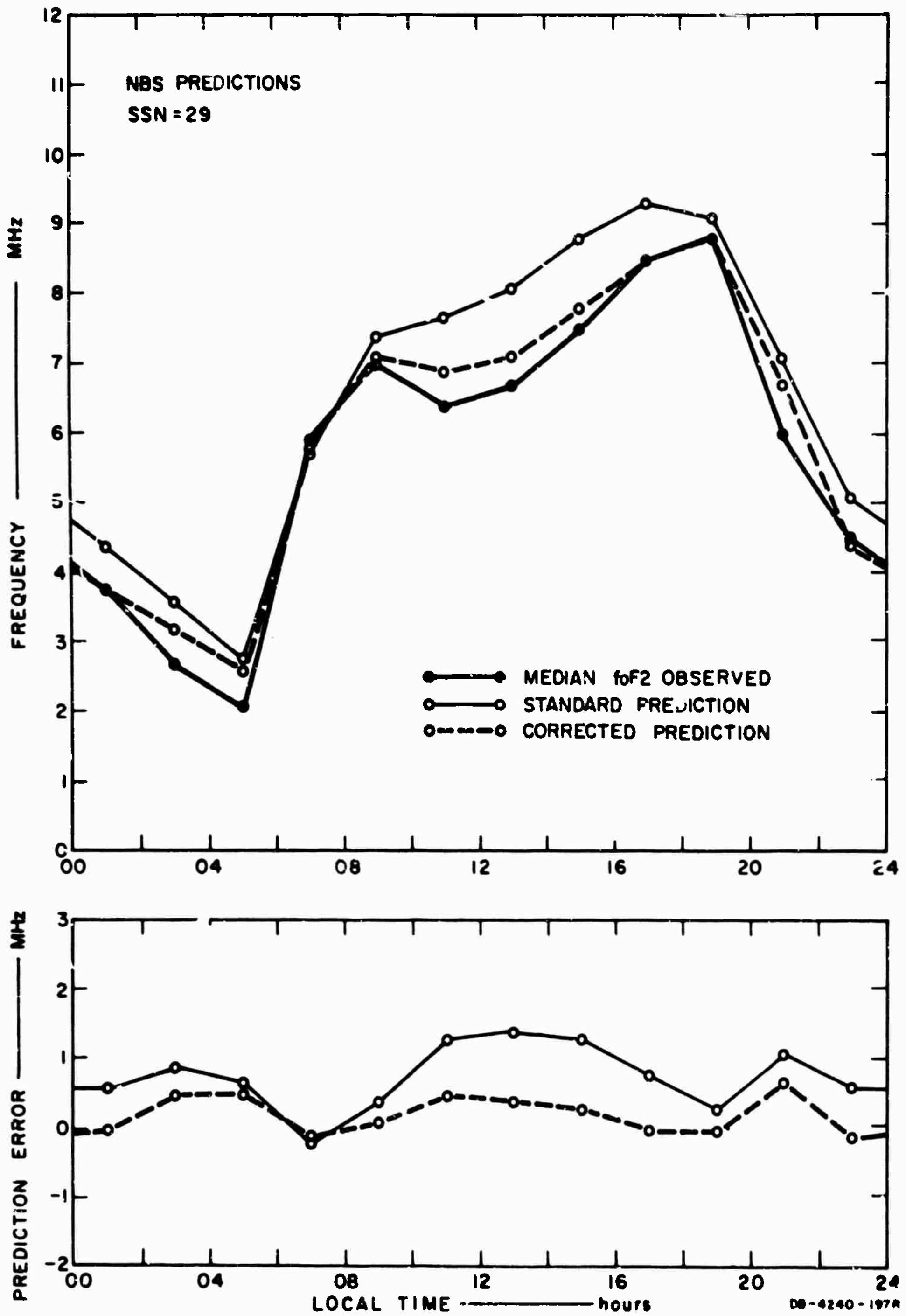

FIG. B-5 COMPARISON OF OBSERVED AND NBS-PREDICTED MONTHLY MEDIAN foF2 FOR AUGUST 1965

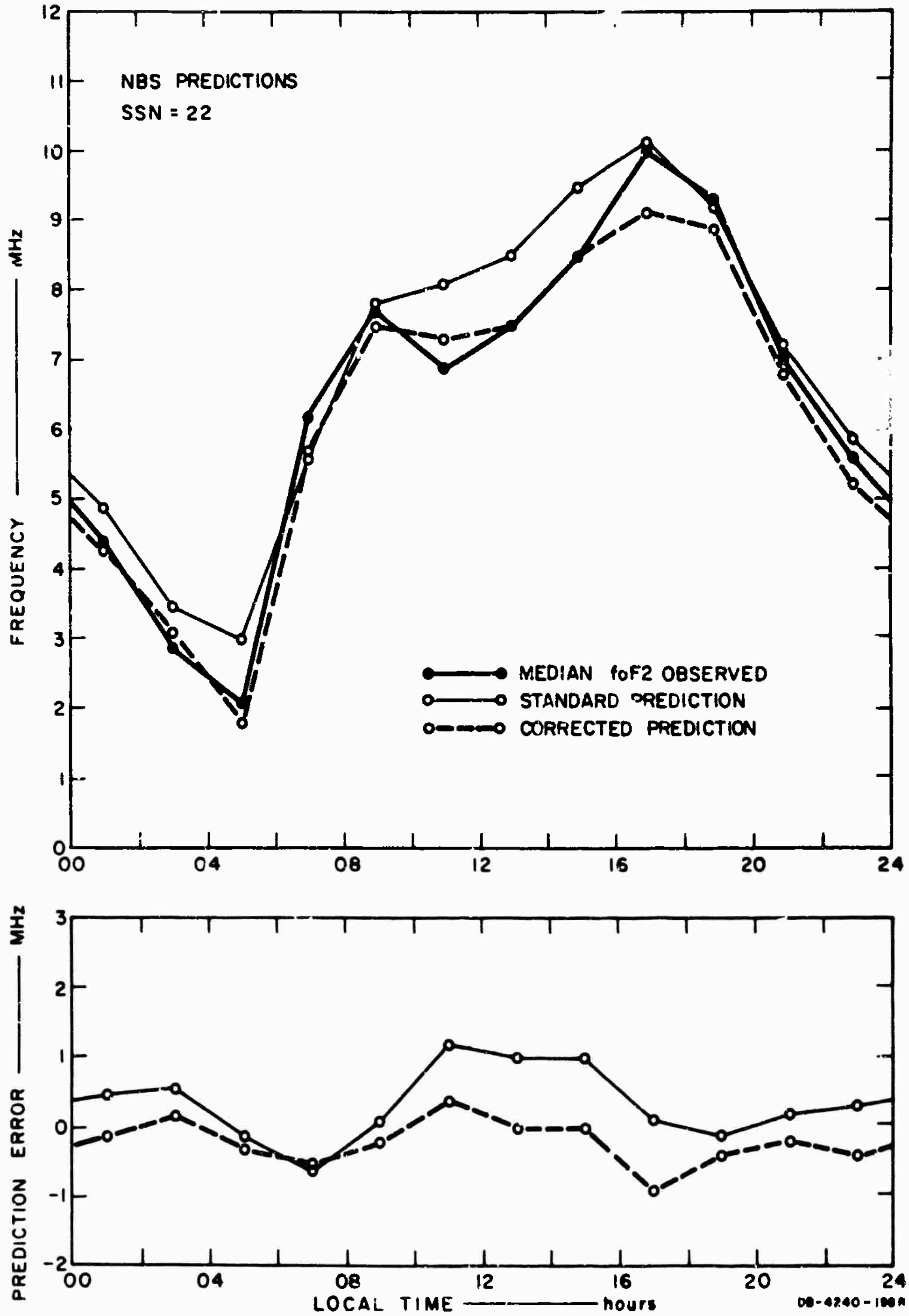

FIG. B-6 COMPARISON OF OBSERVED AND NBS-PREDICTED MONTHLY MEDIAN foF2 FOR SEPTEMBER 1965

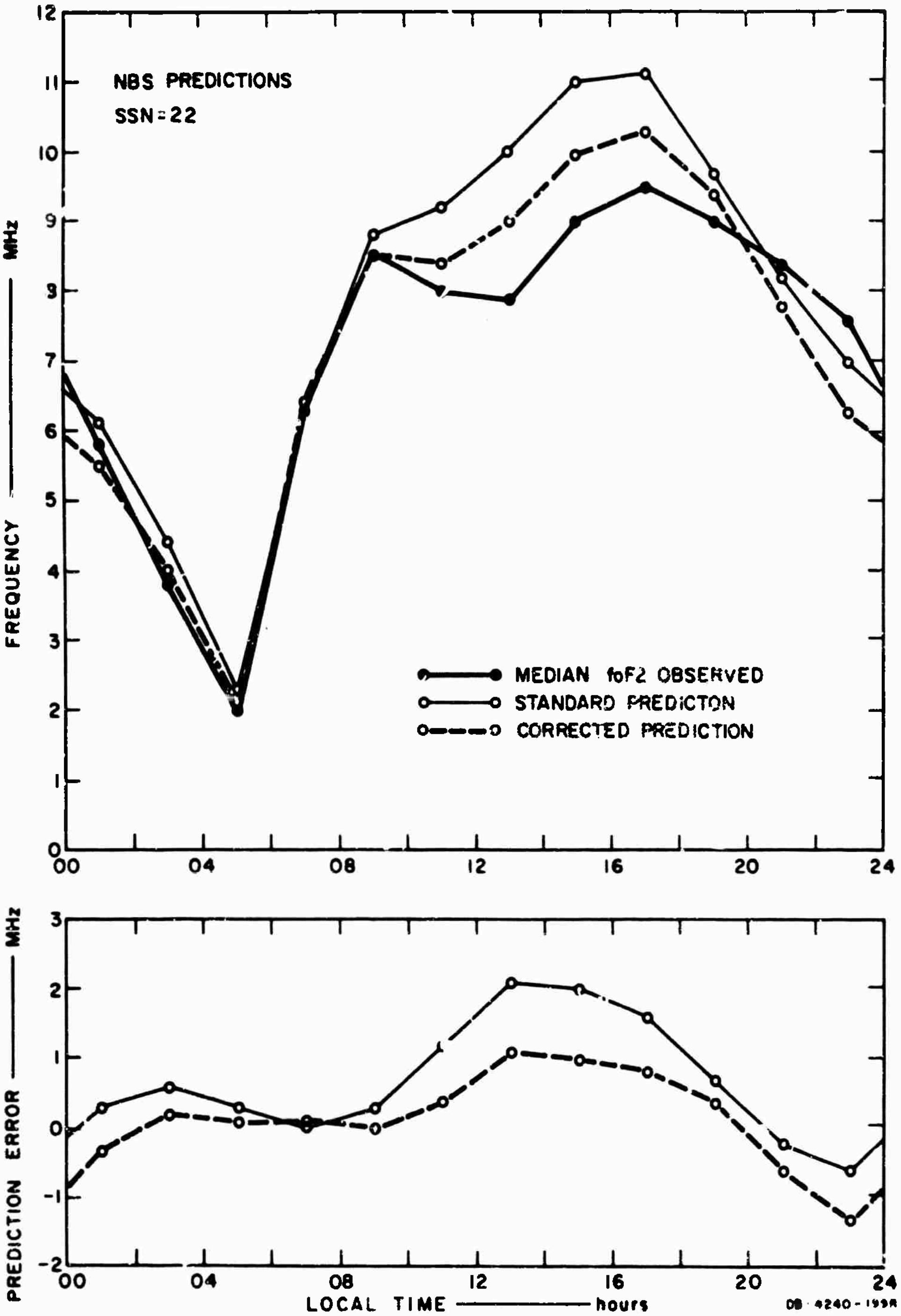

FIG. B-7 COMPARISON OF OBSERVED AND NBS-PREDICTED MONTHLY MEDIAN foF2 FOR OCTOBER 1965

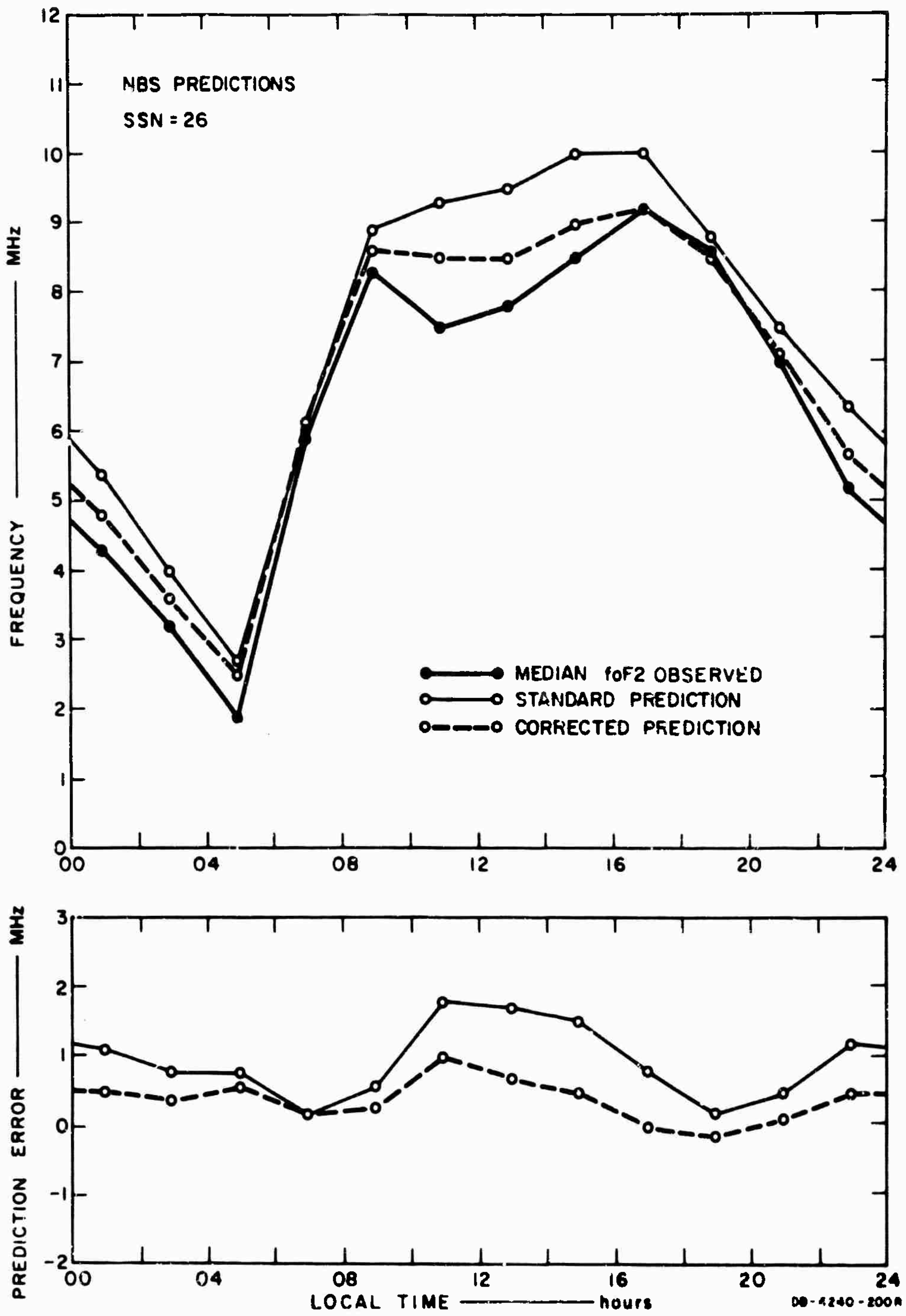

FIG. B-6 COMPARISON OF OBSERVED AND NBS-PREDICTED MONTHLY MEDIAN foF2 FOR NOVEMBER 1965

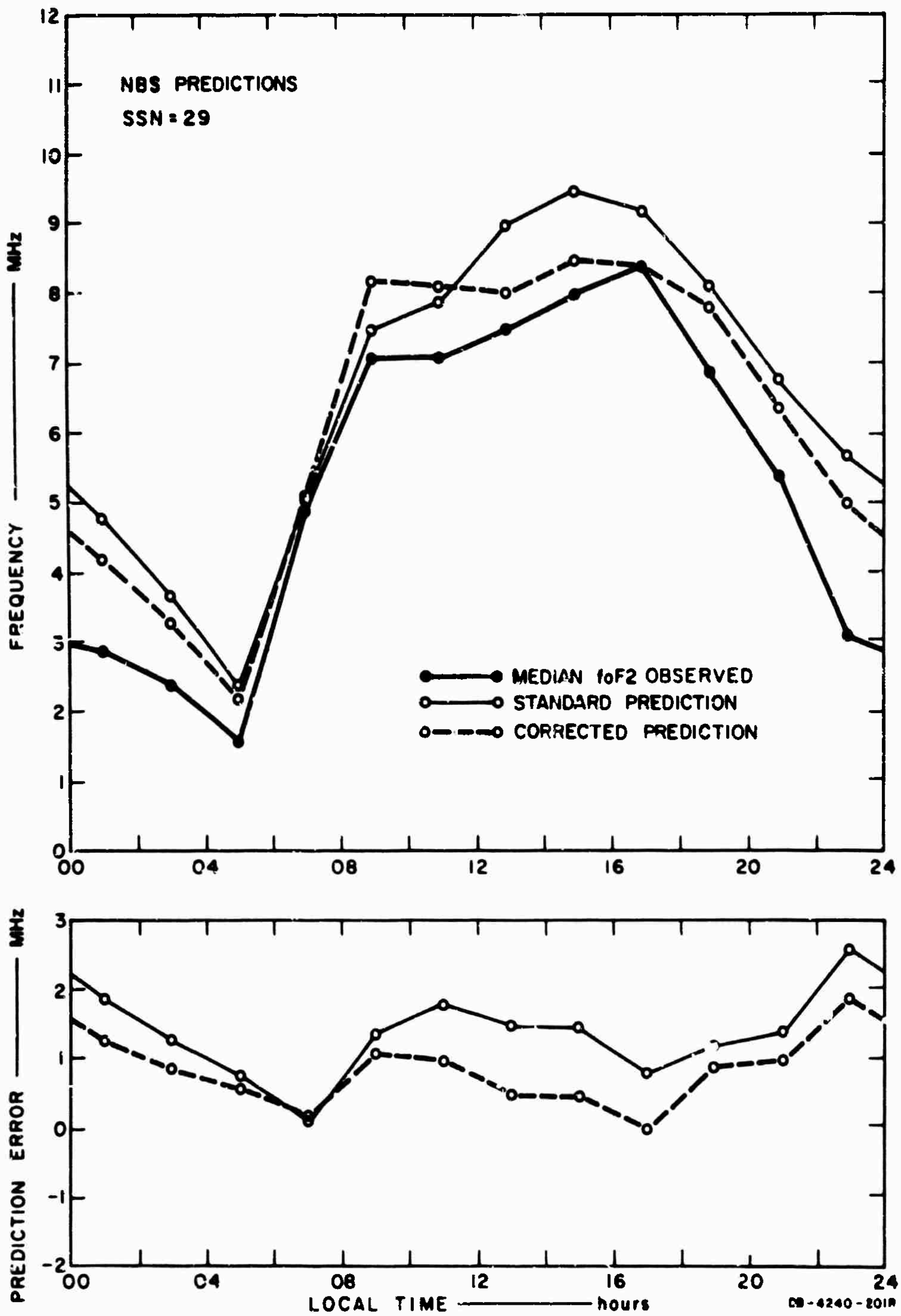

FIG. B-9 COMPARISON OF OBSERVED AND NBS-PREDICTED MONTHLY MEDIAN foF2 FOR DECEMBER 1965

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13. ABSTRACT

Two sets of corrected monthly median MUF (vertical incidence) predictions are compared against the monthly median observed vertical incidence sounder values over Bangkok for the period April 1965 through August 1966. The comparison showed the definite improvement in accuracy that is the primary requirement for new corrected predictions for 1967. New predictions for 1967 were derived by adding a correction to values obtained from a method developed by Stanford Research Institute, long-term predictions can be prepared for several years in advance with this method. The predictions for 1967, corrected for the Bangkok area, typically vary between about 3 MHz in the early morning to about 10 MHz in the late afternoon.

The predicted MUF's for 1967 average about 1 MHz higher than 1966, which means that the 1967 operating frequencies may be increased by about 1 MHz without increasing the expected communication outage.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Predictions						
Maximum usable frequency (MUF)						
F2 layer						
Critical frequency						
Electronic computers						
Statistical evaluation						
SEACORE						